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IN ARCADIA

By Nicholas Poussin, 1594-1665.

NICHOLAS POUSSIN was born at Les Andelys in June, 1594. He early showed ability enough at art to attract the attention of Quentin Varin. Later he studied under Ferdinand Elle at Paris. The Chevalier Marini employed him on illustrations for his poems and assisted him to reach Rome (1624). There Marini died and Poussin was for a time in great distress.

His excellence soon found him patrons. In 1640 he returned to France and was made a court painter by Louis XIII. He went to Rome once more in 1643 and died there in November, 1665.

He was the first great French painter. His style is quite classical in outline and he has had much influence on landscape painting.

"In Arcadia" pictures a group of peasants who are for the moment subdued by reading on a tomb, "He, too, lived in Arcadia."

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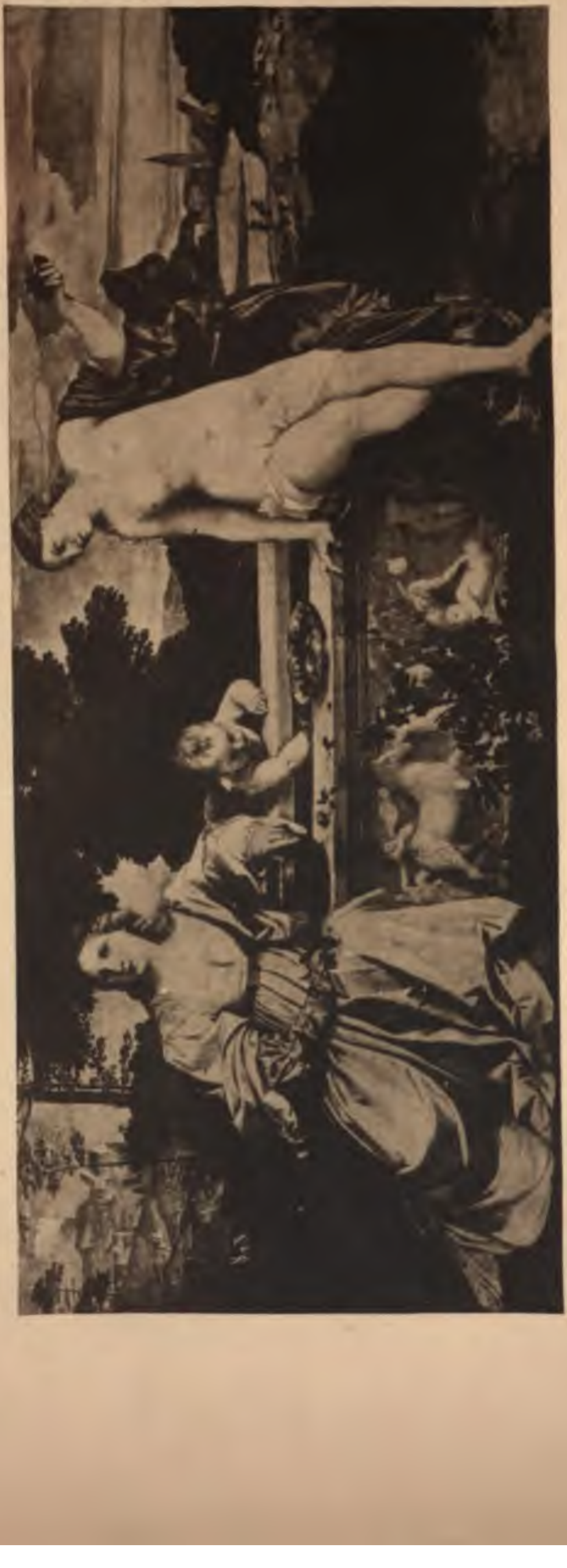

THE BEGINNING OF MODERN MEDICINE

The first attempts made in Christian Europe to revive the study of medicine sought to go back to the Greek and Roman school represented by Hippocrates, Galen, and Celsus. Paracelsus (1493?—1541) was the first to hold himself independent of both the Greco-Roman and the Arabian schools. [illegible] alchemist [illegible] to the "spirit" of the disease. Remedies were supposed to [illegible] the essences of the things from which [illegible] familiarity with alchemy led him to introduce chemical remedies such as laudanum and antimony.

About this time Vesalius (1536-1564) began [illegible] recting in many details the anatomical ideas of the ancients, and led the leaders of the science to depend somewhat on personal dissection and observation instead of entirely on authority. It is said that the heart of a Spanish noble, supposedly dead, seemed to palpitate under his dissecting knife, and that this brought him before the inquisition where he was at first condemned to death, but the sentence afterward commuted to a pilgrimage to the Holy Land. He was shipwrecked when returning, and died of starvation at Zante. His "De Corporis Humani Fabrica" is the first comprehensive study of anatomy in modern times. It adds to and corrects in a number of minor points, the anatomy of the ancients, but his great work was to bring men to see things for themselves.

We now come to the discovery of the circulation of the blood and the beginning of physiology. The Galenic doctrine of the action of the heart and blood was that the blood in the left ventricle of

SACRED AND PROFANE LOVE

By Titian, 1477-1576.

VECELLIO TIZIANO was born in Italy in 1477. When ten years old he was sent to Rome. Here he studied under the Bellinis and Giorgione. On the death of Giovanni Bellini, he completed the work unfinished in the hall of the ducal palace at Venice.

In 1517 at Ferrara he painted his fine "Bacchus and Ariadne" and "The Bacchanal." His portraits also became famous, and he made many trips to do work for princely patrons.

Among his most famous paintings are the "Tribute Money" at Dresden, the "Sacred and Profane Love" in the Borghese gallery, Rome, and the "Assumption of the Virgin" at Venice.

He is one of the world's greatest painters, and the great representative of the Venetian school. As a colorist he was considered unequaled.

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THE BEGINNING OF MODERN MEDICINE

THE FIRST ATTEMPTS made in Christian Europe to revive the study of medicine sought to go back to the Greek and Roman school represented by Hippocrates, Galen, and Celsus. Paracelsus (1490?—1541) was the first to hold himself independent of both the Graeco-Roman and the Arabian schools. He was an astrologer and an alchemist and sought to find a remedy whose "spirit" was opposed to the "spirit" of the disease. Remedies were supposed to contain the essences of the things from which they were drawn. His familiarity with alchemy led him to introduce chemical remedies such as laudanum and antimony.

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Whether or not the heart, besides propelling the blood, giving it motion locally, and distributing it to the body, adds anything else to it,—heat, spirit, perfection,—must be inquired into by and by, and decided upon other grounds. So much may suffice at this time, when it is shown that by the action of the heart the blood is transfused through the ventricles from the veins to the arteries, and distributed by them to all parts of the body.

So much, indeed, is admitted by all [physiologists] both from the structure of the heart and the arrangement and action of its valves. But still they are like persons purblind or groping about in the dark; and then they give utterance to diverse, contradictory, and incoherent sentiments, delivering many things upon conjecture, as we have already had occasion to remark.

The grand cause of hesitation and error in this subject appears to me to have been the intimate connection between the heart and the lungs. When men saw both the vena arteriosa [or pulmonary artery] and the arteriae [or pulmonary veins] losing themselves in the lungs, of course it became a puzzle to them to know how or by what means the right ventricle should distribute the blood to the body, or the left draw it from the venae cavae. This fact is borne witness to by Galen, whose words, when writing against Erasistratus in regard to the origin and use of the veins and the coction of the blood, are the following: "You will reply," he says, "that the effect is so; that the blood is prepared in the liver, and is thence transferred to the heart to receive its proper form and last perfection; a statement which does not appear devoid of reason; for no great and perfect work is ever accomplished at a single effort, or receives its final polish from one instrument. But if this be actually so, then show us another vessel which draws the absolutely perfect blood from the heart, and distributes it as the arteries do the spirits over the whole body." Here then is a reasonable opinion not allowed, because, forsooth, besides not seeing the true means of transit, he could not discover the vessel which should transmit the blood from the heart to the body at large!

But had any one been there in behalf of Erasistratus, and of that opinion which we now espouse, and which Galen himself acknowledges in other respects consonant with reason, to have pointed to the aorta as the vessel which distributes the blood from the heart to the rest of the body, I wonder what would have been the answer of that most ingenious and learned man? Had he said that the artery transmits spirits and not blood, he would indeed sufficiently have answered Erasistratus, who imagined that the arteries contained nothing but spirits; but then he would have contradicted himself, and given a foul denial to that for which he had keenly contended in his writings against this very Erasistratus, to-wit, that the blood in substance is contained in the arteries, and not spirits; a fact which he demonstrated not only by many powerful arguments, but by experiments.

But if the divine Galen will here allow, as in other places he does, "that all the arteries of the body arise from the great artery, and that this takes its origin from the heart; that all these vessels naturally contain and carry blood; that the three semi-lunar valves situated at the orifice of the aorta prevent the return of the blood into the heart, and that nature never connected them with this, the most noble viscus of the body, unless for some most important end;" if, I say, this father of physic admits all these things,—and I quote his own words,—I do not see how he can deny that the great artery is the very vessel to carry the blood, when it has attained its highest term of perfection, from the heart for distribution to all parts of the body. Or would he perchance still hesitate, like all who have come after him, even to the present hour, because he did not perceive the route by which the blood was transferred from the veins to the arteries, in consequence, as I have already said, of the intimate connexion between the heart and lungs? And this difficulty puzzled anatomists not a little, when in their dissections they found the pulmonary artery and left ventricle full of thick, black, and clotted blood, plainly appears, when they felt themselves compelled to affirm that the blood made its way from the right to the left ventricle by sweating through the septum of the heart. But this fancy I have already refuted. A new pathway for the blood must therefore be prepared and thrown open, and being once exposed, no further difficulty will, I believe, be experienced by any one in admitting what I have already proposed in regard to the pulse of the heart and arteries, viz., the passage of the blood from the veins to the arteries, and its distribution to the whole of the body by means of these vessels.

OF THE COURSE BY WHICH THE BLOOD IS CARRIED FROM THE VENA CAVA INTO THE ARTERIES, OR FROM THE RIGHT INTO THE LEFT VENTRICLE OF THE HEART

Since the intimate connexion of the heart with the lungs, which is apparent in the human subject, has been the probable cause of the errors that have been committed on this point, they plainly do amiss who, pretending to speak of the parts of the animals generally, as anatomists for the most part do, confine their researches to the human body alone, and that when it is dead. They obviously act no otherwise than he who, having studied the forms of a single commonwealth, should set about the composition of a general system of polity; or, who, having taken cognizance of the nature of a single field, should imagine that he had mastered the science of agriculture; or who, upon the ground of one particular proposition, should proceed to draw general conclusions.

Had anatomists only been as conversant with the dissection of the lower animals as they are with that of the human body, the matters that have hitherto kept them in perplexity of doubt would, in my opinion, have met them freed from every kind of difficulty.

And, first, in fishes, in which the heart consists of but a single ventricle, they having no lungs, the thing is sufficiently manifest. Here the sac, which is situated at the base of the heart, and is the part analogous to the auricle in man, plainly throws the blood into the heart, and the heart, in its turn, conspicuously transmits it by a pipe or artery, or vessel analogous to an artery; these are the facts which are confirmed by simple ocular inspection, as well as by a division of the vessel, when the blood is seen to be projected by each pulsation of the heart.

The same thing is also not difficult of demonstration in those animals that have either no septum, or, as it were, no more than a single ventricle to the heart, such as toads, frogs, serpents, and lizards, which, although they have lungs in a certain sense, as they have a voice, (and I have many observations by me on the admirable structure of the lungs of these animals, and matters appertaining, which, however, I cannot introduce in this place,) still their anatomy plainly shows that the blood is transferred in them from the veins to the arteries in the same manner as in the higher animals, viz., by the action of the heart; the way, in fact, is patent, open, manifest; there is no difficulty, no room for hesitating about it; for in them the matter stands precisely as it would in man, were the septum of his heart perforated or removed, or one ventricle made out of two; and this being the case, I imagine that no one will doubt as to the way by which the blood may pass from the veins into the arteries.

But as there are actually more animals which have no lungs than there are which be furnished with them, and in like manner a greater number which have only one ventricle than there are which have two, it is open to us to conclude, judging from the mass or multitude of living creatures, that for the major part, and generally, there is an open way by which the blood is transmitted from the veins through the sinuses or cavities of the heart into the arteries.

I have, however, cogitating with myself, seen further, that the same thing obtained more obviously in the embryos of those animals that have lungs; for in the foetus the four vessels belonging to the heart, viz., the vena cava, the vena arteriosa or pulmonary artery, the arteria venalis, or pulmonary vein, and the arteria magna or aorta, are all connected otherwise than in the adult; a fact sufficiently known to every anatomist. The first contact and union of the vena cava with the arteria venosa or pulmonary veins, which occurs before the cava opens properly into the right ventricle of the heart, or gives off the coronary vein, a little above its escape from the liver, is by a lateral anastomosis; this is an ample foramen, of an oval form, communicating between the cava and the arteria venosa, or pulmonary vein, so that the blood is free to flow in the greatest abundance by that foramen from the vena cava into the arteria venosa, or pulmonary vein, and left auricle, and from thence into the left ventricle; and farther, in this foramen ovale, from that part which regards the arteria venosa, or pulmonary vein, there is a thin tough membrane, larger than the opening, extended like an operculum or cover; this membrane in the adult blocking up the foramen, and adhering on all sides, finally closes it up, and almost obliterates every trace of it. This membrane, however, is so contrived in the foetus, that falling loosely upon itself, it permits a ready access to the lungs and heart, yielding a passage to the blood which is streaming from the cava, and hindering the tide at the same time from flowing back into that vein. All things, in short, permit us to believe that in the embryo the blood must constantly pass by this foramen from the vena cava into the arteria venosa, or pulmonary vein, and from thence into the left auricle of the heart; and having once entered there, it can never regurgitate.

Another union is that by the vena arteriosa, or pulmonary artery, and is effected when the vessel divides into two branches after its escape from the right ventricle of the heart. It is as if to the two trunks already mentioned a third were superadded, a kind of arterial canal, carried obliquely from the vena arteriosa, or pulmonary artery, to perforate and terminate in the arteria magna or aorta. In the embryo, consequently, there are, as it were, two aortas, or two roots of the arteria magna, springing from the heart. This canalis arteriosus shrinks gradually after birth, and is at length and finally almost entirely withered, and removed like the umbilical vessels.

The canalis arteriosus contains no membrane or valve to direct or impede the flow of the blood in this or that direction; for at the root of the vena arteriosa, or pulmonary artery, of which the canalis arteriosus is the continuation in the foetus, there are three sigmoid or semilunar valves, which open from within outwards, and oppose no obstacle to the blood flowing in this direction or from the right ventricle into the pulmonary artery or aorta; but they prevent all regurgitation from the aorta or pulmonic vessels back upon the right ventricle; closing with perfect accuracy, they oppose an effectual obstacle to everything of the kind in the embryo. So that there is also reason to believe that when the heart contracts, the blood is regularly propelled by the canal or passage indicated from the right ventricle into the aorta.

What is commonly said in regard to these two great communications, to wit, that they exist for the nutrition of the lungs, is both improbable and inconsistent; seeing that in the adult they are closed up, abolished, and consolidated, although the lungs, by reason of their heat and motion, must then be presumed to reqüire a larger supply of nourishment. The same may be said in regard to the assertion that the heart in the embryo does not pulsate, that it neither acts nor moves, so that nature was forced to make these communications for the nutrition of the lungs. This is plainly false; for simple inspection of the incubated egg, and of the embryo just taken out of the uterus, shows that the heart moves precisely in them as in adults, and that nature feels no such necessity. I have myself repeatedly seen these motions, and Aristotle is likewise witness of their reality. "The pulse," he observes, "inheres in the very constitution of the heart, and appears in the beginning, as is learned both from the dissection of living animals, and the formation of the chick in the egg." But we further observe, that the passages in question are not only pervious up to the period of birth in man as well as in other animals, as anatomists in general have described them, but for several months subsequently, in some indeed for several years, not to say for the whole course of life; as, for example, in the goose, snipe, and various birds, and many of the smaller animals. And this circumstance it was, perhaps, that imposed upon Botallus, who thought he had discovered a new passage for the blood from the vena cava into the left ventricle of the heart; and I own that when I met with the same arrangement in one of the larger members of the mouse family, in the adult state, I was myself led to something of a like conclusion.

From this it will be understood that in the human embryo, and in the embryo of animals in which the communications are not closed, the same thing happens, namely, that the heart by its motion propels the blood by obvious and open passages from the vena cava into the aorta through the cavities of both the ventricles; the right one receiving the blood from the auricle, and propelling it by the vena arteriosa, or pulmonary artery, and its continuation, named the ductus arteriosus, into the aorta; the left, in like manner, charged by the contraction of its auricle, which has received its supply through the foramen ovale from the vena cava, contracting, and projecting the blood through the root of the aorta into the trunk of that vessel.

In embryos, consequently, whilst the lungs are yet in a state of inaction, performing no function, subject to no motion any more than if they had not been present, nature uses the two ventricles of the heart as if they formed but one, for the transmission of the blood. The condition of the embryos of those animals which have lungs, whilst these organs are yet in abeyance and not employed, is the same as that of those animals which have no lungs.

So clearly, therefore, does it appear in the case of the foetus, viz., that the heart by its action transfers the blood from the vena cava into the aorta, and that by a route as obvious and open, as if in the adult the two ventricles were made to communicate by the removal of their septum. Since, then we find that in the greater number of animals, in all, indeed, at a certain period of their existence, the channels for the transmission of the blood through the heart are so conspicuous, we have still to inquire wherefore in some creatures—those, namely, that have warm blood, and that have attained to the adult age, man among the number—we should not conclude that the same thing is accomplished through the substance of the lungs, which in the embryo, and at a time when the function of these organs is in abeyance, nature effects by the direct passages described, and which, indeed, she seems compelled to adopt through want of a passage by the lungs; or wherefore it should be better (for nature always does that which is best) that she should close up the various open routes, which she formerly made use of in the embryo and foetus, and still uses in all other animals; not only opening up no new apparent channels for the passage of the blood, therefore, but even entirely shutting up those which formerly existed.

And now the discussion is brought to this point, that they who inquire into the ways by which the blood reaches the left ventricle of the heart and pulmonary veins from the vena cava, will pursue the wisest course if they seek by dissection to discover the causes why in the larger and more perfect animals of mature age, nature has rather chosen to make the blood percolate the parenchyma of the lungs, than as in other instances chosen a direct and obvious course—for I assume that no other path or mode of transit can be entertained. It must be either because the larger and more perfect animals are warmer, and when their adult heat greater—ignited, as I might say, and requiring to be damped or mitigated; therefore it may be that the blood is sent through the lungs, that it may be tempered by the air that is inspired, and prevented from boiling up, and so becoming extinguished, or something of the sort. But to determine these matters and explain them satisfactorily, were to enter on a speculation in regard to the office of the lungs and the ends for which they exist; and upon such a subject, as well as what pertains to eventilation, to the necessity and use of the air, etc., as also to the variety and diversity of organs that exist in the bodies of animals in connexion with these matters, although I have made a vast number of observations, still, lest I should be held as wandering too wide of my present purpose, which is the use and motion of the heart, and be charged of speaking of things beside the question, and rather complicating and quitting than illustrating it, I shall leave such topics till I can more conveniently set them forth in a treatise apart. And, now, returning to my immediate subject, I go on with what yet remains for demonstration, viz., that in the more perfect and warmer adult animals, and man, the blood passes from the right ventricle of the heart by the vena arteriosa, or pulmonary artery, into the lungs, and thence by the arteriae venosae, or pulmonary veins, into the left auricle, and thence into the left ventricle of the heart. And, first, I shall show that this may be so, and then I shall show that it is so in fact.

THE BLOOD PERCOLATES THE SUBSTANCE OF THE LUNGS FROM THE RIGHT VENTRICLE OF THE HEART INTO THE PULMONARY VEINS AND LEFT VENTRICLE

That this is possible, and that there is nothing to prevent it from being so, appears when we reflect on the way in which water percolating the earth produces springs or rivulets, or when we speculate on the means by which the sweat passes through the skin, or the urine through the parenchyma of the kidneys. It is well known that persons who use the Spa waters, or those of La Madonna, in the territories of Padua, or others of an acidulous or vitriolated nature, or who simply swallow drinks by the gallon, pass all off again within an hour or two by urine. Such a quantity of liquid must take some short time in the concoction; it must pass through the liver; (it is allowed by all that the juices of the food we consume pass twice through this organ in the course of the day;) it must flow through the veins, through the parenchyma of the kidneys, and through the ureters into the bladder.

To those, therefore, whom I hear denying that the blood, aye, the whole mass of the blood may pass through the substance of the lungs, even as the nutritive juices percolate the liver, asserting that such a proposition to be impossible, and by no means to be entertained as credible, I reply, with the poet, that they are of that race of men who, when they will, assent full readily, and when they will not, by no manner of means; who, when their assent is wanted, fear, and when it is not, fear not to give it.

The parenchyma of the liver is extremely dense, so is that of the kidney; the lungs, again, are of a much looser texture, and if compared with the kidneys are absolutely spongy. In the liver there is no forcing, no impelling power; in the lungs the blood is forced on by the pulse of the right ventricle, the necessary effect of whose impulse is the distension of the vessels and pores of the lungs. And then the lungs, in respiration, are perpetually rising and falling; motions, the effect of which must needs be to open and shut the pores and vessels, precisely as in the case of a sponge, and of parts having a spongy structure, when they are alternately compressed and again suffered to expand. The liver, on the contrary, remains at rest, and is never seen to be dilated and constricted. Lastly, if no one denies the possibility of the whole of the ingested juices passing through the liver, in man, oxen, and the larger animals generally, in order to reach the vena cava, and for this reason, that if nourishment is to go on, these juices must needs get into the veins, and there is no other way but the one indicated, why should not the same arguments be held of avail for the passage of the blood in adults through the lungs? Why not, with Columbus, that skillful and learned anatomist, maintain and believe the like, from the capacity and structure of the pulmonary vessels; from the fact of the pulmonary veins and ventricle corresponding with them, being always found to contain blood, which must needs have come from the veins, and by no other passage save through the lungs? Columbus, and we also, from what precedes, from dissections, and other arguments, conceive the thing to be clear. But as there are some who admit nothing unless upon authority, let them learn that the truth I am contending for can be confirmed from Galen's own words, namely, that not only may the blood be transmitted from the pulmonary artery into the pulmonary veins, then into the left ventricle of the heart, and from thence into the arteries of the body, but that this is effected by the ceaseless pulsation of the heart and the motion of the lungs in breathing.

There are, as every one knows, three sigmoid or semilunar valves situated at the orifice of the pulmonary artery, which effectually prevent the blood sent into the vessel from returning into the cavity of the heart. Now Galen, explaining the uses of these valves, and the necessity for them, employs the following language: "There is everywhere a mutual anastomosis and inosculation of the arteries with the veins, and they severally transmit both blood and spirit, by certain invisible and undoubtedly very narrow passages. Now if the mouth of the vena arteriosa, or pulmonary artery, had stood in like manner continually open, and nature had found no contrivance for closing it when requisite, and opening it again, it would have been impossible that the blood could ever have passed by the invisible and delicate mouths, during the contractions of the thorax, into the arteries; for all things are not alike readily attracted or repelled; but that which is light is more readily drawn in, the instrument being dilated, and forced out again when it is contracted, than that which is heavy; and in like manner is anything drawn more rapidly along an ample conduit, and again driven forth, than it is through a narrow tube. But when the thorax is contracted, the pulmonary veins, which are in the lungs, being driven inwardly, and powerfully compressed on every side, immediately force out some of the spirit they contain, and at the same time assume a certain portion of blood by these subtile mouths; a thing that could never come to pass were the blood at liberty to flow back into the heart through the great orifice of the pulmonary artery. But its return through the great opening being prevented, when it is compressed on every side, a certain portion of it distils into the pulmonary veins by the minute orifices mentioned." And shortly afterwards, in the very next chapter, he says: "The more the thorax contracts, the more it strives to force out the blood, the more exactly do these membranes (viz., the sigmoid valves) close up the mouth of the vessel, and suffer nothing to regurgitate." The same fact he has also alluded to in a preceding part of the tenth chapter: "Were there no valves, a three-fold inconvenience would result, so that the blood would then perform this lengthened course in vain; it would flow inwards during the diastoles of the lungs, and fill all their arteries; but in the systoles, in the manner of the tide, it would ever and anon, like the Euripus, flow backwards and forwards by the same way, with a reciprocating motion, which would nowise suit the blood. This, however, may seem a matter of little moment; but if it meantime appear that the function of respiration suffer, then I think it would be looked upon as no trifle," etc. And again, and shortly afterwards: "And then a third inconvenience, by no means to be thought lightly of, would follow, were the blood moved backwards durings the expiration, had not our Maker instituted those supplementary membranes [the sigmoid valves]." Whence, in the eleventh chapter he concludes: "That they have all a common use, (to wit, the valves), and that it is to prevent regurgitation or backward motion; each, however, having a proper function, the one set drawing matters from the heart, and preventing their return, the other drawing matters into the heart, and preventing their escape from it. For nature never intended to distress the heart with needless labour, neither to bring aught into the organ which it had been better to have kept away, nor to take from it again aught which it was requisite should be brought. Since, then, there are four great orifices in all, two in either ventricle, one of these induces, the other educes." And again he says: "Farther, since there is one vessel, consisting of a simple tunic, implanted in the heart, and another having a double tunic, extending from it, (Galen is here speaking of the right side of the heart, but I extend his observations to the left side also,) a kind of reservoir had to be provided, to which both belonging, the blood should be drawn in by one, and sent out by the other."

This argument Galen adduces for the transit of the blood by the right ventricle from the vena cava into the lungs; but we can use it with still greater propriety, merely changing the terms, for the passage of the blood from the veins through the heart into the arteries. From Galen, however, that great man, that father of physicians, it clearly appears that the blood passes through the lungs from the pulmonary artery into the minute branches of the pulmonary veins, urged to this both by the pulses of the heart and by the motions of the lungs and thorax; that the heart, moreover, is incessantly receiving and expelling the blood by and from its ventricles, as from a magazine, or cistern, and for this end is furnished with four sets of valves, two serving for the induction and two for the eduction of the blood, lest, like the Euripus, it should be incommodiously sent hither and thither, or flow back into the cavity which it should have quitted, or quit the part where its presence was required, and so the heart be oppressed with labour in vain, and the office of the lungs be interfered with. Finally, our position that the blood is continually passing from the right to the left ventricle, from the vena cava into the aorta, through the porous structure of the lungs, plainly appears from this, that since the blood is incessantly sent from the right ventricle into the lungs by the pulmonary artery, and in like manner is incessantly drawn from the lungs into the left ventricle, as appears from what precedes and the position of the valves, it cannot do otherwise than pass through continuously. And then, as the blood is incessantly flowing into the right ventricle of the heart, and is continually passed out from the left, as appears in like manner, and as is obvious both to sense and reason, it is impossible that the blood can do otherwise than pass continually from the vena cava into the aorta.

Dissection consequently shows distinctly what takes place [in regard to the transit of the blood] in the greater number of animals, and indeed in all, up to the period of their [foetal] maturity; and that the same thing occurs in adults is equally certain, both from Galen's words, and what has already been said on the subject, only that in the former the transit is effected by open and obvious passages, in the latter by obscure porosities of the lungs and the minute inosculations of vessels. Whence it appears that, although one ventricle of the heart, the left to wit, would suffice for the distribution of the blood over the body, and its eduction from the vena cava, as indeed is done in those creatures that have no lungs, nature, nevertheless, when she ordained that the same blood should also percolate the lungs, saw herself obliged to add another ventricle, the right, the pulse of which should force the blood from the vena cava through the lungs into the cavity of the left ventricle. In this way, therefore, it may be said that the right ventricle is made for the sake of the lungs, and for the transmission of the blood through them, not for their nutrition; seeing it were unreasonable to suppose that the lungs required any so much more copious supply of nutriment, and that of so much purer and more spiritous a kind, as coming immediately from the ventricle of the heart, than either the brain with its peculiarly pure substance, or the eyes with their lustrous and truly admirable structure, or the flesh of the heart itself, which is more commodiously nourished by the coronary artery.

OF THE QUANTITY OF BLOOD PASSING THROUGH THE HEART FROM THE VEINS TO THE ARTERIES: AND OF THE CIRCULAR MOTION OF THE BLOOD

Thus far I have spoken of the passages of the blood from the veins into the arteries, and of the manner in which it is transmitted and distributed by the action of the heart; points to which some, moved either by the authority of Galen or Columbus, or the reasonings of others, will give in their adhesion. But what remains to be said upon the quantity and source of the blood which thus passes, is of so novel and unheard-of character, that I not only fear injury to myself from the envy of the few, but I tremble lest I have mankind at large for my enemies, so much doth wont and custom, that become as another nature, and doctrine once sown and that hath struck deep root, and respect for antiquity influence all men: Still the die is cast, and my trust is in my love of truth, and the candour that inheres in cultivated minds. And sooth to say, when I surveyed my mass of evidence, whether derived from vivisections, and my various reflections on them, or from the ventricles of the heart and the vessels that enter into and issue from them, the symmetry and size of these conduits,—for nature doing nothing in vain, would never have given them so large a relative size without a purpose,—or from the arrangement and intimate structure of the valves in particular, and of the other parts of the heart in general, with many other things besides, I frequently and seriously bethought me, and long revolved in my mind, what might be the quantity of blood that was transmitted, in how short a time its passage might be effected, and the like; and not finding it possible that this could be supplied by the juices of the ingested aliment without the veins on the one hand becoming drained, and the arteries on the other getting ruptured, through the excessive charge of blood, unless the blood should somehow find its way from the arteries into the veins, and so return to the right side of the heart; I began to think whether there might not be A MOTION, AS IT WERE, IN A CIRCLE. Now this I afterward found to be true; and I finally saw that the blood, forced by the action of the left ventricle into the arteries, was distributed to the body at large, and its several parts, in the same manner as it is sent through the lungs, impelled by the right ventricle into the pulmonary artery, and that it then passes through the veins and along the vena cava, and so round to the left ventricle in the manner already indicated. Which motion may be allowed to call circular, in the same way as Aristotle says that the air and rain emulate the circular motion of the superior bodies; for the moist earth, warmed by the sun, evaporates; the vapours drawn upwards are condensed, and descending in the form of rain, moisten the earth again; and by this arrangement are generations of living things produced; and in like manner too are tempests and meteors engendered by the circular motion, and by the approach and recession of the sun.

And so, in all likelihood, does it come to pass in the body, through the motion of the blood; the various parts are nourished, cherished, quickened by the warmer, more perfect, vaporous, spiritous, and, as I may say, alimentive blood; which, on the contrary, in contact with these parts becomes cooled, coagulated, and, so to speak, effete; whence it returns to its sovereign the heart, as if to its source, or to the inmost home of the body, there to recover its state of excellence, or perfection.

Here it resumes its due fluidity and receives an infusion of natural heat—powerful, fervid, a kind of treasury of life, and is impregnated with spirits, and it might be said with balsam; and thence it is again dispersed; and all this depends on the motion and action of the heart.

The heart, consequently, is the beginning of life; the sun of the microcosm, even as the sun in his turn might well be designated the heart of the world; for it is the heart by whose virtue and pulse the blood is moved, perfected, made apt to nourish, and is preserved from corruption and coagulation; it is the household divinity which, discharging its function, nourishes, cherishes, quickens the whole body, and is indeed the foundation of life, the source of all action. But of these things we shall speak more opportunely when we come to speculate upon the final cause of the motion of the heart.

Hence, since the veins are the conduits and vessels that transport the blood, they are of two kinds, the cava and the aorta; and this is not by reason of there being two sides of the body, as Aristotle has it, but because of the differences of office; nor yet, as is commonly said, in consequence of any diversity of structure, for in many animals, as I have said, the vein does not differ from the artery in the thickness of its tunics, but solely in virtue of their several destinies and uses. A vein and an artery, both styled vein by the ancients, and that not undeservedly, as Galen has remarked, because the one, the artery to-wit, is the vessel which carries the blood from the heart to the body at large, the other or vein of the present day bringing it back from the general system to the heart; the former is the conduit from, the latter the channel to, the heart; the latter contains the cruder, effete blood, rendered unfit for nutrition; the former transmits the digested, perfect, peculiarly nutritive fluid.

EDU[illegible]

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FLORA

By Titian, 1477-1576. At Florence.

EDUCATION

In the second volume of this series we illustrated the education of the Spartans, and the contributions to the science by Plato and Aristotle. In all of this the child was subordinated to the state. The Spartans made him a Stoic: Plato and Aristotle would have made him a philosopher. Rome, on the other hand, as we saw in the essays of Quintilian and Plutarch (volume III.), trained her youth to be orators. They were either born statesmen, generals, jurisconsults, or got their skill in these fields by actual practice; in eloquence alone were they given any formal training.

The education of the Middle Ages was either that of scholasticism in the monasteries or of knighthood in the tournament. The two forms were in strong contrast. The young knight was brought up to serve his mistress, the monk was taught to think woman a temptation from the devil. The knight learned to ride, joust, swim, shoot with the bow, hawk, play chess, and make verses in Italian or Provençal. The monk learned grammar, logic, rhetoric, Latin, mathematics, philosophy, astrology, and perhaps alchemy and music. The knight's training was mostly physical. The monk's was intellectual, but narrow, bigoted, harsh, and formal.

With the Renaissance came a new interest in the classical authors studied in the original. Universities sprung up all over Europe, and the higher classes, who had been intellectually the most ignorant during the Middle Ages, became the most enlightened. The Reformation did much to bring this education within the reach of the middle orders.

John Sturm (1507-1589) of Strasburg introduced the study of pure Ciceronian Latin into the schools in place of the spoken Latin of the scholastics. The influence of this act has been enormous both for good and bad. He was an embodiment of true scholarship, but his work led to euphemism and artificial refinements.

Montaigne (1533-1592) gives a good picture of the education of his time. He makes a strong plea for the fostering and development of the originality of the child. His essay on education is given in volume V.

Wolfgang Ratke (1571-?) did a great deal to systematize teaching. His principal rules are these: 1. Begin everything with prayer. 2. Do all things in order, following nature. 3. Do one thing at a time. 4. Emphasize by frequent repetition. 5. Teach first in the mother tongue. 6. Proceed from the mother tongue to the other languages. 7. Do not beat children (as did the monastic schools) to make them learn. Give time for play. Do not teach more than two hours at a time. Teach pupils to love their masters. Let them learn the substance, not the words. 8. Let there be uniformity in teaching and text books. 9. Teach things first, then the reasons for them. Give examples before rules. Teach languages from the authors themselves. 10. Teach inductively and by experiment.

As a counterpoise to the new development of Protestant schools, the Jesuits established schools all over Catholic Europe. Lower education they made include grammar and syntax. Then followed rhetoric and the languages. The pupils were taught not only to read and write but to speak classical Latin. The higher studies began with Aristotle's science and followed with his philosophy. The climax of the course was a four years' training in theology.

The educator most influential on the future developments of the science was probably, however, Comenius. His great principle was to follow nature closely, for example, in learning a dead language to learn words and things together as we do the mother tongue. His outline of the principles of education is given below.

COMENIUS

JOHN AMOS COMENIUS (KOMENSKI) was born in Moravia, 1592. His parents, who belonged to the Moravian Brethren, died when he was a child. He went to an elementary school at Stassnick, and entered the Latin school at the rather late age of sixteen. After attending the universities of Amsterdam and Heidelberg, he was appointed to the Moravian Brethren's school at Prerau. In 1618 he was placed over the church and school at Fulneck. In 1621 the Spanish troops swept away his property. Three years later the persecution of the Protestants in that locality began and in 1627 Comenius felt compelled to seek peace in Poland. He was summoned to England in 1641 to superintend the improvement of the public schools, but the civil war was on and he had to leave with his work unaccomplished. For a while he found a home with Louis de Geer, a rich Dutch merchant, but in 1648 returned to Poland to be head bishop of his church. The next few years were spent in his church work and in the founding of a model school.

Trouble broke out between the Moravians and Poles and Comenius again lost all his possessions, finding a home at last with Lawrence de Geer, the son of his former patron. He died in 1670. He helped to open education to the lower classes and continually sought to find a method of instruction that would follow the example of nature.

EDUCATIONAL IDEAS

THE PRINCIPLES OF FACILITY IN TEACHING AND IN LEARNING

1. We have already considered the means by which the educationist may attain his goal with certainty, we will now proceed to see how these means can be suited to the minds of the pupils, so that their use may be easy and pleasant.

2. Following in the footsteps of nature we find that the process of education will be easy

(i.) If it begin early, before the mind is corrupted.

(ii.) If the mind be duly prepared to receive it.

(iii.) If it proceed from the general to the particular.

(iv.) And from what is easy to what is more difficult.

(v.) If the pupil be not overburdened by too many subjects.

(vi.) And if progress be slow in every case.

(vii.) If the intellect be forced to nothing to which the natural bent does not incline it, in accordance with its age and with the right method.

(viii.) If everything be taught through the medium of the senses.

(ix.) And if the use of everything taught be continually kept in view.

(x.) If everything be taught according to one and the same method.

These, I say, are the principles to be adopted if education is to be easy and pleasant.

FIRST PRINCIPLE

3. Nature begins by a careful selection of materials.

For instance, for hatching a bird she selects fresh eggs and those that contain pure matter. If the formation of the chicken have already begun, it is in vain to expect any result.

4. Imitation.—The architect who wishes to erect a building, needs a clear plot of ground, and, if there be a house already standing there, he must pull it down before he can build the new one.

5. The artist, too, does his best work on a clean canvas. If it have already been painted on, or be dirty or rough, it must be cleaned or smoothed before he can use it.

6. For the preservation of precious ointments, empty jars must be procured, or those that are in use must be carefully cleansed of their contents.

7. The gardener, too, prefers to plant young trees, or, if he takes them too old, cuts off the branches in order that the sap may not be dissipated. For this reason Aristotle placed "privation" among the principles of nature, for he held that it was impossible

to impress a new form on any material until the old one had been removed.

8. Deviation.—It follows from this: (1) That it is best to devote the mind to the pursuit of wisdom while it is still fresh, and before it has acquired the habit of dissipating its strength over a variety of occupations; and that the later the education begins, the harder it will be for it to obtain a hold, because the mind is already occupied by other things. (2) That the result must be bad if a boy be instructed by several teachers at once, since it is scarcely possible for them all to use the same method, and, if they do not, the boy's mind is drawn first in one direction and then in another, and its development is thus hindered. (3) That it shows great lack of judgment if moral instruction be not made the first point when the education of children or of older boys is commenced; since, when they have been taught to control their feelings, they will be the more fit to receive other instruction. Horse-tamers keep a horse under absolute control with an iron bit, and ensure its obedience before they teach it its paces. Rightly does Seneca say: "First learn virtue, and then wisdom, since without virtue it is difficult to learn wisdom." And Cicero says: "Moral philosophy makes the mind fit to receive the seeds of further knowledge."

9. Rectification.—Therefore

(i.) Education should be commenced early.

(ii.) The pupil should not have more than one teacher in each subject.

(iii.) Before anything else is done, the morals should be rendered harmonious by the master's influence.

SECOND PRINCIPLE

10. Nature prepares its material so that it actually strives to attain the form.

Thus the chicken in the egg, when sufficiently formed, seeks to develop itself still further, moves, and bursts the shell or breaks through it with its beak. After escaping from its prison, it takes pleasure in the warmth and nutriment provided by its mother, opens its beak expectantly and swallows its food greedily. It rejoices to find itself under the open sky, exercises its wings, and, later on, uses them with enjoyment; in a word, it displays a keen desire to fulfill all its natural functions, though throughout the whole process of development it advances step by step.

11. Imitation.—The gardener also must bring it about that the plant, properly provided with moisture and with warmth, take pleasure in its vigorous growth.

12. Deviation.—Therefore, those who drive boys to their studies, do them great harm. For what result can they expect? If a man have no appetite, but yet takes food when urged to do so, the result can only be sickness and vomiting, or at least indigestion and indisposition. On the other hand, if a man be hungry, he is eager to take food, digests it readily, and easily converts it into flesh and blood. Thus Isocrates says: "He who is anxious to learn will also be learned." And Quintilian says: "The acquisition of knowledge depends on the will to learn, and this cannot be forced."

13. Rectification.—Therefore

(i.) The desire to know and to learn should be excited in boys in every possible manner.

(ii.) The method of instruction should lighten the drudgery of learning, that there may be nothing to hinder the scholars or deter them from making progress with their studies.

14. The desire to learn is kindled in boys by parents, by masters, by the school, by the subjects of instruction, by the method of teaching, and by the authority of the state.

15. By parents, if they praise learning and the learned in the presence of their children, or if they encourage them to be industrious by promising them nice books and clothes, or some other pretty thing; if they commend the teachers (especially him to whom they entrust their sons) as much for their friendly feeling towards the pupils as for their skill in teaching (for love and admiration are the feelings most calculated to stimulate a desire for imitation); finally, if, from time to time, they send the child to him with a small present. In this way they will easily bring it about that the children like their lessons and their teachers, and have confidence in them.

16. By the teachers, if they are gentle and persuasive, and do not alienate their pupils from them by roughness, but attract them by fatherly sentiments and words; if they commend the studies that they take in hand on account of their excellence, pleasantness, and ease; if they praise the industrious ones from time to time (to the little ones they may give apples, nuts, sugar, etc.); if they call the

children to them, privately or in the class, and show them pictures of the things that they must learn, or explain to them optical or geometrical instruments, astronomical globes, and such-like things that are calculated to excite their admiration; or again, if they occasionally give the children some message to carry to their parents. In a word, if they treat their pupils kindly they will easily win their affections, and will bring it about that they prefer going to school to remaining at home.

17. The school itself should be a pleasant place, and attractive to the eye both within and without. Within, the room should be bright and clean, and its walls should be ornamented by pictures. These should be either portraits of celebrated men, geographical maps, historical plans, or other ornaments. Without, there should be an open place to walk and to play in (for this is absolutely necessary for children, as we shall show later), and there should also be a garden attached, into which the scholars may be allowed to go from time to time and where they may feast their eyes on trees, flowers and plants. If this be done, boys will, in all probability, go to school with as much pleasure as to fairs, where they always hope to see and hear something new.

18. The subjects of instruction themselves prove attractive to the young, if they are suited to the age of the pupil and are clearly explained; especially if the explanation be relieved by a humorous or at any rate by a less serious tone. For thus the pleasant is combined with the useful.

19. If the method is to excite a taste for knowledge, it must, in the first place, be natural. For what is natural takes place without compulsion. Water need not be forced to run down a mountain-side. If the dam, or whatever else holds in back, be removed, it flows down at once. It is not necessary to persuade a bird to fly; it does so as soon as the cage is opened. The eye and the ear need no urging to enjoy a fine painting or a beautiful melody that is presented to them. In all these cases it is more often necessary to restrain than to urge on. The requisites of a natural method are evident from the preceding chapter and from the rules that follow.

In the second place, if the scholars are to be interested, care must be taken to make the method palatable, so that everything, no matter how serious, may be placed before them in a familiar and attractive manner; in the form of a dialogue, for instance, by pitting the boys against one another to answer and explain riddling questions, comparisons, and fables. But of this more in the proper place.

20. The civil authorities and the managers of schools can kindle the zeal of the scholars by being present at public performances (such as declarations, disputations, examinations, and promotions), and by praising the industrious ones and giving them small presents (without respect to person).

THIRD PRINCIPLE

21. Nature develops everything from beginnings, which, though insignificant in appearance, possess great potential strength.

For instance, the matter out of which a bird is to be formed consists of a few drops, which are contained in a shell, that they may be easily warmed and hatched. But these few drops contain the whole bird potentially, since, later on, the body of the chicken is formed from the vital principle which is concentrated in them.

22. Imitation.—In the same way a tree, no matter how large it may be, is potentially contained in the kernel of its fruit or in the shoot at the end of one of its branches. If one or the other of these be placed in the earth, a whole tree will be produced by the inner force that it contains.

23. Terrible Deviation.—In direct opposition to this principle a terrible mistake is generally made in school. Most teachers are at pains to place in the earth plants instead of seeds, and trees instead of shoots, since, instead of starting with the fundamental principles, they place before their pupils a chaos of diverse conclusions or the complete texts of authors. And yet it is certain that instruction rests on a very small number of principles, just as the earth is composed of four elements (though in diverse forms); and that from theses principles (in accordance with the evident limits of their powers of differentiation) an unlimited number of results can be deduced, just as, in the case of a tree, hundreds of branches, and thousands of leaves, blossoms, and fruits are produced from the original shoot. Oh! may God take pity on our age, and open some man's eyes, that he may see aright the true relations in which things stand to one another, and may impart his knowledge to the rest of mankind. With God's assistance I hope, in my Synopsis of Christian Wisdom, to give an earnest of my efforts to do so, in the modest

hope that it may be of use to others whom God, in due season, may call to carry on the work.

24. Rectification.—In the meantime we may draw three conclusions:

(i.) Every art must be contained in the shortest and most practical rules.

(ii.) Each rule must be expressed in the shortest and clearest words.

(iii.) Each rule must be accompanied by many examples, in order that the use of the rule may be quite clear when fresh cases arise.

FOURTH PRINCIPLE

25. Nature advances from what is easy to what is more difficult.

For example, the formation of an egg does not begin with the hardest part, the shell, but with the contents. These are at first covered by a membrane; it is not till later that the hard shell appears. The bird that learns to fly accustoms itself first to stand on its legs, then to move its wings gently, then to do so with more force until it can raise itself from the ground, and last of all gains sufficient confidence to fly through the air.

26. Imitation.—In the same way a carpenter's apprentice learns, first to fell trees, then to saw them into planks and fasten them together, and finally to build complete houses of them.

27. Various Deviations.—It is therefore wrong to teach the unknown through the medium of that which is equally unknown, as is the case:

(i.) If boys who are beginning Latin are taught the rules in Latin. This is just as if the attempt were made to explain Hebrew by Hebrew rules, or Arabic by Arabic rules.

(ii.) If these same beginners are given as assistance a Latin-German instead of a German-Latin dictionary. For they do not want to learn their mother-tongue by the aid of Latin, but to learn Latin through the medium of the language that they already know. (On this error we will say more in chap. xxii.).

(iii.) If boys are given a foreign teacher who does not understand their language. For if they have no common medium through which they can hold communications with him, and can only guess at what he is saying, can anything but a Tower of Babel be the result?

(iv.) A deviation is made from the right method of teaching, if boys of all nations (i. e., French, German, Bohemian, Polish, or Hungarian boys) are taught in accordance with the same rules of grammar (those of Melanchthon or of Ramus *26*, for example,) since each of these languages stands in its own particular relation to Latin, and this relation must be well understood if Latin is to be thoroughly taught to boys of these several nationalities.

28. Rectification.—These errors may be avoided

(i.) If the teachers and their pupils talk the same language.

(ii.) If all explanations are given in the language that the pupils understand.

(iii.) If grammars and dictionaries are adapted to the language through the medium of which the new one is to be learned (that is to say, the Latin Grammar to the mother-tongue, and Greek Grammar to the Latin language).

(iv.) If the study of a new language be allowed to proceed gradually and in such a way that the scholar learn first to understand (for this is the easiest), then to write (for here there is time for consideration), and lastly to speak (which is the hardest, because the process is so rapid).

(v.) If, when Latin is combined with German, the German be placed first as the best known, and the Latin follow.

(vi.) If the subject-matter be so arranged that the pupils get to know, first, that which lies nearest to their mental vision, then that which is moderately near, then that which is more remote, and lastly, that which is farthest off. Therefore, if boys are being taught something for the first time (such as logic or rhetoric), the illustrations should not be taken from subjects that cannot be grasped by the scholars, such as theology, politics, or poetry, but should be derived from the events of every-day life. Otherwise the boys will understand neither the rules nor their application.

(vii.) If boys be made to exercise, first their senses (for this is the easiest), then the memory, then the comprehension, and finally the judgment. In this way a graded sequence will take place; for all knowledge begins by sensuous perception; then through the medium of the imagination it enters the province of the memory; then, by dwelling on the particulars, comprehension of the universal arises; while finally comes judgment on the facts that have been grasped, and in this way our knowledge is firmly established.

FIFTH PRINCIPLE

29. Nature does not overburden herself, but is content with a little.

For instance, she does not demand two chickens from one egg, but is satisfied if one be produced. The gardener does not insert a number of grafts on one stock, but two at most, if he consider it very strong.

30. Deviation.—The mental energies of the scholar are therefore dissipated if he have to learn many things at once, such as grammar, rhetoric, poetic, Greek, etc., in one year (cf. the previous chapter, Principle 4).

SIXTH PRINCIPLE

31. Nature does not hurry, but advances slowly.

For example, a bird does not place its eggs in the fire, in order to hatch them quickly, but lets them develop slowly under the influence of natural warmth. Neither, later on, does it cram its chickens with food that they may mature quickly (for this would only choke them), but it selects their food with care and gives it to them gradually in the quantities that their weak digestion can support.

32. Imitation.—The builder, too, does not erect the walls on the foundations with undue haste and then straightway put on the roof; since, unless the foundations were given time to dry and become firm, they would sink under the superincumbent weight, and the whole building would tumble down. Large stone buildings, therefore, cannot be finished within one year, but must have a suitable length of time allotted for their construction.

33. Nor does the gardener expect a plant to grow large in the first month, or to bear fruit at the end of the first year. He does not, therefore, tend and water it every day, nor does he warm it with fire or with quicklime, but is content with the moisture that comes from heaven and with the warmth that the sun provides.

34. Deviation.—For the young, therefore, it is torture

(i.) If they are compelled to receive six, seven, or eight hours' class instruction daily, and private lessons in addition.

(ii.) If they are overburdened with dictations, with exercises, and with the lessons that they have to commit to memory, until nausea and, in some cases, insanity is produced.

If we take a jar with a narrow mouth (for to this we may compare a boy's intellect) and attempt to pour a quantity of water into it violently, instead of allowing it to trickle in drop by drop, what will be the result? Without doubt the greater part of the liquid will flow over the side, and ultimately the jar will contain less than if the operation had taken place gradually. Quite as foolish is the action of those who try to teach their pupils, not as much as they can assimilate, but as much as they themselves wish; for the faculties need to be supported and not to be overburdened, and the teacher, like the physician, is the servant and not the master of nature.

35. Rectification.—The ease and the pleasantness of study will therefore be increased:

(i.) If the class instruction be curtailed as much as possible, namely to four hours, and if the same length of time be left for private study.

(ii.) If the pupils be forced to memorize as little as possible, that is to say, only the most important things; of the rest they need only grasp the general meaning.

(iii.) If everything be arranged to suit the capacity of the pupil, which increases naturally with study and age.

SEVENTH PRINCIPLE

36. Nature compels nothing to advance that is not driven forward by its own mature strength.

For instance, a chicken is not compelled to quit the egg before its limbs are properly formed and set; is not forced to fly before its feathers have grown; is not thrust from the nest before it is able to fly well, etc.

A tree, too, does not put forth shoots before it is forced to do so by the sap that rises from the roots, nor does it permit fruit to appear before the leaves and blossoms formed by the sap seek further development, nor does it permit the blossoms to fall before the fruit that they contain is protected by a skin, nor the fruit to drop before it is ripe.

37. Deviation.—Now the faculties of the young are forced:

(i.) If the boys are compelled to learn things for which their age and capacity are not yet suited.

(ii.) If they are made to learn by heart or do things that have not first been thoroughly explained and demonstrated to them.

38. Rectification.—From what has been said, it follows

(i.) That nothing should be taught to the young, unless it is not only permitted but actually demanded by their age and mental strength.

(ii.) That nothing should be learned by heart that has not been thoroughly grasped by the understanding. Nor should any feat of memory be demanded unless it is absolutely certain that the boy's strength is equal to it.

(iii.) That nothing should be set boys to do until its nature has been thoroughly explained to them, and rules for procedure have been given.

EIGHTH PRINCIPLE

39. Nature assists its operations in every possible manner.

For example, an egg possesses its own natural warmth, but this is assisted by the warmth of the sun and by the feathers of the bird that hatches it. God, the father of nature, takes forethought for this. The newly-hatched chicken, also, is warmed by the mother as long as is necessary, and is trained by her in the various functions of life. This we can see in the case of storks, who assist their young by taking them on their backs and bearing them round the nest while they exercise their wings. In the same way nurses help little children. They teach them first to raise their heads and then to sit up; later on, to stand on their legs, and to move their legs preparatory to walking; then by degrees to walk and step out firmly. When they teach them to speak they repeat words to them and point out the objects that the words denote.

40. Deviation.—It is therefore cruelty on the part of a teacher if he set his pupils work to do without first explaining it to them thoroughly, or showing them how it should be done, and if he do not assist them in their first attempts; or if he allow them to toil hard, and then loses his temper if they do not succeed in their endeavors.

What is this but to torture the young? it is just as if a nurse were to force a child to walk, while it is still afraid to stand on its legs, and beat it when it failed to do so. Nature's teaching is very different, and shows that we ought to have patience with the weak as long as their strength is insufficient.

41. Rectification.—From this it follows:

(i.) That no blows should be given for lack of readiness to learn (for, if the pupil do not learn readily, this is the fault of no one but the teacher, who either does not know how to make the pupil receptive of knowledge or does not take the trouble to do so).

(ii.) That the subjects that have to be learned by the pupils should be so thoroughly explained to them, that they can understand them as well as they understand their five fingers.

(iii.) That, as far as is possible, instruction should be given through the senses, that it may be retained in the memory with less effort.

42. (For example, the sense of hearing should always be conjoined with that of sight, and the tongue should be trained in combination with the hand. The subjects that are taught should not merely be taught orally, and thus appeal to the ear alone, but should be pictorially illustrated, and thus develop the imagination by the help of the eye. Again, the pupils should learn to speak with their mouths and at the same time to express what they say with their hands, that no study may be proceeded with before what has already been learned is thoroughly impressed on the eyes, the ears, the understanding, and the memory. With this object, it is desirable to represent pictorially, on the walls of the class-room, everything that is treated of in the class, by putting up either precepts and rules or pictures and diagrams illustrative of the subjects taught. If this is done, it is incredible how much it assists a teacher to impress his instructions on the pupils' minds. It is also useful if the scholars learn to write down in their note-books or among their collections of idioms everything that they hear or read, since in this way the imagination is assisted and it is easier to remember them later on.

NINTH PRINCIPLE

43. Nothing is produced by nature of which the practical application is not soon evident.

For example, when a bird is formed it is soon evident that the wings are intended for flying and the legs for running. In the same way every part of a tree has its use, down to the skin and the bloom that surround the fruit.

Therefore

44. Imitation.—The task of the pupil will be made easier, if the master, when he teaches him anything, show him at the same

time its practical application in everyday life. This rule must be carefully observed in teaching languages, dialectic, arithmetic, geometry, physics, etc. If it be neglected, the things that you are explaining will seem to be monsters from the new world, and the attitude of the pupil, who is indifferent whether they exist or no, will be one of belief rather than of knowledge. When things are brought under his notice and their use explained to him, they should be put into his hands that he may assure himself of his knowledge and may derive enjoyment from its application.

Therefore

45. **Those things only should be taught whose application can be easily demonstrated.**

TENTH PRINCIPLE

46. Nature is uniform in all its operations.

For instance, the production of all birds, and, indeed, of all living creatures, resembles that of any single bird which you may choose. It is only in the minor details that there are differences. So too in the case of plants, the development of one plant from its seed, the planting and the growth of a single tree, serve as illustrations of the way in which all the others, without exception, develop. One leaf on a tree resembles all the others, and in this respect does not change from year to year.

47. Deviation.—Differences of method, therefore, confuse the young, and make their studies distasteful to them, since not only do different teachers use different systems, but even individual teachers vary their method. For example, languages are taught in one way, dialectic in another, though both might be brought under the same method, in accordance with the harmony of the universe, and the universal and intimate relations that exist between objects and words.

48. Rectification.—Henceforth, therefore

(i.) The same method of instruction must be used for all the sciences, the same for all the arts, and the same for all languages.

(ii.) In each school the same arrangement and treatment should be adopted for all studies.

(iii.) The class-books for each subject should, as far as is possible, be of the same edition.

In this way difficulties will be avoided and progress will be made easy.—The Great Didactic.

TRANSLATION OF KEATING.

THE BEGINNING OF MODERN PHILOSOPHY

WE SAW in the second volume of this series that Greek philosophy had a consecutive development starting with Thales and reaching its climax in Aristotle. Modern philosophy, beginning with Descartes, forms another connected story of the evolution of thought. The Greek philosophers attacked mainly the problem of what is the permanent reality in the universe: modern philosophy has begun to see that the problem of the true nature of the universe is bound up with the question of the real nature of the self.

Descartes (1596-1650) tried to sweep away all uncertainties and start from one absolutely certain fact, "Cogito, ergo sum," as he expressed it,—"I think, and in so thinking I exist." Only what appealed to his mind as clearly as this prime truth was to be accepted as a fact. He believed in the existence of God because he thought there must exist some perfect, infinite Being which is the source of imperfect, finite man. He felt that he could trust his senses as to the material world because such a Being would not deceive. Therefore he accepted the existence of matter as a substance co-ordinate with mind, the essence of mind being thought, the essence of matter being extension, the source of both being God.

Out of this conception of the duality of the universe, rose the question of how mind and matter can act on each other. Geulincx (1625-1669) denied the possibility of any interaction. He thought mind and matter to be like two clocks that run in harmony, not because they interact, but because both are controlled by their maker. Thus Malebranche (1638-1715) declared that "we see all

THE ADORATION OF THE SHEPHERDS

By Correggio, 1494-1534.

ANTONIO ALLEGRI (CORREGGIO) was born at Correggio, near Parma, in 1494. He takes the name by which he is known from his native town. But little is preserved about his life, and most of this is disputed. He early attained local success, and painted the pictures in the cathedral and the church of St. John at Parma. Among his other famous pictures are the "Marriage of St. Catharine" in the Louvre, and "The Nativity" at Dresden.

He was a facile painter, and a great technician, but could not express thought as could Michael Angelo, nor feeling as did Raphael.

[illegible] PHILOSOPHY

[illegible] reach [illegible]

[illegible] right [illegible] There- [illegible] inate [illegible] matter [illegible]

things in God," that "our minds exist in God as matter exists in space," that things are known to us only through ideas, and these ideas come from God.

Spinoza (1632-1677) transformed the dualism of Descartes into a monism by making God the sole true substance, and mind and matter only His manifestations. Leibnitz (1646-1716) sought to overcome Descartes' dualism by supposing the universe to be, not one great unity, but made up of an infinite number of individualities, or, as he called them, monads. He makes the essence of substance to be life, mind, and activity. Each monad is an individuality, but some only move, others live, others think though unconsciously, the highest are self-conscious. God is the supreme monad whence all others radiate as light from the sun. The harmony of the world was established at its creation. Thus Leibnitz practically added the conception of life and mind to the atomic theory of the Greek Demokritos.

Locke (1632-1674) took up the examination of the contents of the mind anew. He opposed Descartes' doctrine of innate ideas and Leibnitz's belief in the possibility of unconscious thought. He thought the soul to be at the beginning a *tabula rosa*, an "unmarked tablet," and that all ideas come from experience. His analysis of the ideas of the mind marks the beginning of psychology. He agreed with Descartes in our certainty of our own existence, argued for the existence of God as the cause of our existence, and believed in the existence of things or matter as the cause or occasion of our ideas. Where he got his principle of causality he does not explain.

This idea of Locke's that substance is an abstract idea presupposed as the cause of our sensations is the starting ground of Berkeley's idealism. Let us take an illustration. What can we actually mean by a thing—for instance, a bell? We have a sensation of sound, another of sight, a feeling of hardness or resistance, a temperature sensation of coldness, perhaps a bitter taste of the brass. All these sensations are states of our own consciousness, but they are continually recurring together, and we take for granted something that we call a bell as their cause. Yet all we really experience is a cluster of sensations. Now Berkeley admits that we do have such clusters of ideas, and that consequently our experience is exactly the same under his system as under the most out and out materialism. Where Berkeley differs from materialism is in his answer to the question, "What is the real nature of that something which we presuppose as the cause of these groups of sensations?" Berkeley's argument, in brief, is this: All we can actually experience is our self and the states of our own consciousness—all mental; the only self-acting cause we know is our own will—also mental; since, then, the only reality and the only cause we can actually know are mental, what right have we to suppose this unknown something to be anything but mental? Thus Berkeley argues dead matter out of existence and in its stead puts God, the cause of all our sensations. Nature is a symbolism through which God speaks to us.

Hume (1711-1776) hurled philosophy from idealism into scepticism. Starting from Locke's theory that all knowledge comes from experience, he argued against the possibility of any sure knowledge or science whatever. He declared that he could not find the self at all, that he saw no necessary connection between ideas, that cause and effect are simply habits of thought formed by custom, and that therefore any certain knowledge is impossible.

This scepticism of Hume woke Kant (1724-1804) "out of his dogmatic slumber," and incited him to examine the elements of the mind. His problem was, "How is mathematics possible? How is natural science possible? Is metaphysics possible?" He found elements in the mind besides those that come from experience. He showed that although the contents of our minds are given by experience, the form is furnished by the active mind itself. Space and time, cause and effect, design, reciprocity are all forms of thought given by the active mind to phenomena, and the possibility of any consciousness whatever depends upon the unifying activity of the self. Things in themselves we cannot experience, phenomena must come under the laws of thought in order to be correlated with the rest of our consciousness. This is Kant's answer to the problem of the possibility of knowledge. The laws of thought hold good for all experience, but cannot go beyond it. Nature in itself we cannot experience, but only its manifestations as the phenomena of our consciousnesss. The soul is a thing in itself; we can never grasp it. But for the very reason that it is not a part of our experience, the soul in itself may not be bound by the laws of experience and the will may be free. This is the necessary basis of morality. So, too, God may exist outside the field of experience, and faith is always possible.

The above outline is best amplified in the words of the thinkers themselves. The development of philosophy since Kant belongs to a later volume.

DESCARTES

Rene Descartes was born March 30, 1596, in the province of Touraine. His mother died of consumption a few days after his birth, and he was not expected to live. From 1604 to 1612 he was under the Jesuits at La Flèche. The next year he was sent to Paris to see life. After two years spent to this purpose, he busied himself in his studies for two more, and then in 1617 enlisted as a volunteer in the war against the Netherlands.

His military life lasted four years. While in camp during the winter of 1619-20, he saw the possibility of solving geometrical theorems by algebra. Thus was born analytical geometry. He also thought that he could apply his method to all changes, considering them as matter in motion.

In 1641 he published his Meditations. These tried to sweep away all preconceived notions and start from the one certain fact "Cogito, ergo sum," "I think and in thinking I exist." Only what he could apperceive with absolute clearness would he accept as true. We have pointed out the development of his system in the introduction above. It certainly has furnished much of the basis of all succeeding philosophy. He accepted God in order to account for himself, and the facts given by the senses because so clearly given and because God would not deceive. As regards the changes in the material world, his mathematical training led him to reduce them all under the laws of mechanics, but his fear of religious persecution prevented him giving these views full publicity.

In 1649 he went to Stockholm on an invitation from Queen Christina, but caught cold a few months later and died February 11, 1650.

MEDITATIONS

ON THE FIRST PHILOSOPHY, IN WHICH THE EXISTENCE OF GOD, AND THE REAL DISTINCTION OF MIND AND BODY ARE DEMONSTRATED

Meditation I.

OF THE THINGS OF WHICH WE MAY DOUBT

Several years have now elapsed since I first became aware that I had accepted, even from my youth, many false opinions for true, and that consequently what I afterwards based on such principles was highly doubtful; and from that time I was convinced of the necessity of undertaking once in my life to rid myself of all the opinions I had adopted, and of commencing anew the work of building from the foundation, if I desired to establish a firm and abiding superstructure in the sciences. But as this enterprise appeared to me to be one of great magnitude, I waited until I had attained an age so mature as to leave me no hope that at any stage of life more advanced I should be better able to execute my design. On this account, I have delayed so long that I should henceforth consider I was doing wrong were I still to consume in deliberation any of the time that now remains for action. To-day, then, since I have opportunely freed my mind from all cares, [and am happily disturbed by no passions], and since I am in the secure possession of leisure in a peaceable retirement, I will at length apply myself earnestly and freely to the general overthrow of all my former opinions. But, to this end, it will not be necessary for me to show that the whole of these are false—a point, perhaps, which I shall never reach; but as even now my reason convinces me that I ought not the less carefully to withhold belief from what is not entirely certain and indubitable, than from what is manifestly false, it will be sufficient to justify the rejection of the whole if I shall find in each some ground for doubt: nor for this purpose will it be necessary even to deal with each belief individually, which would be truly an endless labour; but, as the removal from below the foundation necessarily involves the downfall of the whole edifice, I will at once approach the criticism of the principles on which all my former beliefs rested.

All that I have, up to this moment, accepted as possessed of the highest truth and certainty, I received either from or through the senses. I observed, however, that these sometimes misled us; and it is the part of prudence not to place absolute confidence in that by which we have even once been deceived.

But it may be said, perhaps, that, although the senses occasionally mislead us respecting minute objects, and such as are so far removed from us as to be beyond the reach of close observation, there are yet many other of their informations (presentations), of the truth of which it is manifestly impossible to doubt; as for example, that I am in this place, seated by the fire, clothed in a winter dressing-gown, that I hold in my hands this piece of paper, with other intimations of the same nature. But how could I deny that I possess these hands and this body, and withal escape being classed with persons in a state of insanity, whose brains are so disordered and clouded by dark bilious vapors as to cause them pertinaciously to assert that they are monarchs when they are in the greatest poverty; or clothed [in gold] and purple when destitute of any covering; or that their head is made of clay, their body of glass, or that they are gourds? I should certainly be not less insane than they, were I to regulate my procedure according to examples so extravagant.

Though this be true, I must nevertheless here consider that I am a man, and that, consequently, I am in the habit of sleeping, and representing to myself in dreams those same things, or even sometimes others less probable, which the insane think are presented to them in their waking moments. How often have I dreamt that I was in these familiar circumstances,—that I was dressed, and occupied this place by the fire, when I was lying undressed in bed? At the present moment, however, I certainly look upon this paper with eyes wide awake; the head which I now move is not asleep; I extend this hand consciously and with express purpose, and I perceive it; the occurrences in sleep are not so distinct as all this. But I cannot forget that, at other times, I have been deceived in sleep by similar illusions; and, attentively considering those cases, I perceive so clearly that there exist no certain marks by which the state of waking can ever be distinguished from sleep, that I feel greatly astonished; and in amazement I almost persuade myself that I am now dreaming.

Let us suppose, then, that we are dreaming, and that all these particulars—namely, the opening of the eyes, the motion of the head, the forth-putting of the hands—are merely illusions; and even that we really possess neither an entire body nor hands such as we see. Nevertheless, it must be admitted at least that the objects which appear to us in sleep are, as it were, painted representations which could not have been formed unless in the likeness of realities; and, therefore, that those general objects, at all events,—namely, eyes, a head, hands, and an entire body—are not simply imaginary, but really existent. For, in truth, painters themselves, even when they study to represent sirens and satyrs by forms the most fantastic and extraordinary, cannot bestow upon them natures absolutely new, but can only make a certain medley of the members of different animals; or if they chance to imagine something so novel that nothing at all similar has ever been seen before, and such as is, therefore, purely fictitious and absolutely false, it is at least certain that the colours of which this is composed are real.

And on the same principle, although these general objects, viz., [a body], eyes, a head, hands, and the like, be imaginary, we are nevertheless absolutely necessitated to admit the reality at least of some other objects still more simple and universal than these, of which, just as of certain real colours, all those images of things, whether true or real, or false and fantastic, that are found in our consciousness (cogitatio), are formed.

To this class of objects seem to belong corporeal nature in general and its extension; the figure of extended things, their quantity and magnitude, and their number, as also the place in, and the time during, which they exist, and other things of the same sort. We will not, therefore, perhaps reason illegitimately if we conclude this that Physics, Astronomy, Medicine, and all the other sciences that have for their end the consideration of composite objects, are indeed of a doubtful character; but that Arithmetic, Geometry, and the other sciences of the same class, which regard merely the simplest and most general objects, and scarcely inquire whether or not these are really existent, contain somewhat that is certain and indubitable: for whether I am awake or dreaming, it remains true that two and three make five, and that a square has but four sides; nor does it seem possible that truths so apparent can ever fall under a suspicion of falsity [or incertitude].

Nevertheless, the belief that there is a God who is all-powerful, and who created me, such as I am, has for a long time, obtained steady possession of my mind. How, then, do I know that He has not arranged that there should be neither earth, nor sky, nor any extended thing, nor figure, nor magnitude, nor place, providing at the same time, however, for [the rise in me of the perceptions of all these objects, and] the persuasion that these do not exist otherwise than as I perceive them? And further, as I sometimes think that others are in error respecting matters of which they believe themselves to possess a perfect knowledge, how do I know that I am not also deceived each time that I add together two and three, or number the sides of a square, or form some judgment still more simple, if more simple indeed can be imagined? But perhaps Deity has not been willing that I should be thus deceived, for He is said to be supremely good. If, however, it were repugnant to the goodness of Deity to have created me subject to constant deception, it would seem likewise to be contrary to His goodness to allow me to be occasionally deceived; and yet it is clear that this is permitted. Some, indeed, might perhaps be found who would be disposed rather to deny the existence of a Being so powerful than to believe that there is nothing certain. But let us for the present refrain from opposing this opinion, and grant that all which is here said of Deity is fabulous: nevertheless, in whatever way it be supposed that I reached the state in which I exist, whether by fate, or chance, or by an endless series of antecedents and consequents, or by any other means, it is clear (since to be deceived and to err is a certain defect) that the probability of my being so imperfect as to be the constant victim of deception, will be increased exactly in proportion as the power possessed by the cause, to which they assign my origin, is lessened. To these reasonings I have assuredly nothing to reply, but am constrained at last to avow that there is nothing of all that I formerly believed to be true of which it is impossible to doubt, and that not through thoughtlessness or levity, but from cogent and maturely considered reasons; so that henceforward, if I desire to discover anything certain, I ought not the less carefully to refrain from assenting to those same opinions than to what might be shown to be manifestly false.

But it is not sufficient to have made these observations; care must be taken likewise to keep them in remembrance. For those old and customary opinions perpetually recur—long and familiar usage giving them the right of occupying my mind, even almost against my will, and subduing my belief; nor will I lose the habit of deferring to them and confiding in them so long as I shall consider them to be what in truth they are, viz., opinions to some extent doubtful, as I have already shown, but still highly probable, and such as it is much more reasonable to believe than to deny. It is for this reason I am persuaded that I shall not be doing wrong, if, taking an opposite judgment of deliberate design, I become my own deceiver, by supposing, for a time, that all those opinions are entirely false and imaginary, until at length, having thus balanced my old by my new prejudices, my judgment shall no longer be turned aside by perverted usage from the path that may conduct to the perception of truth.

For I am assured that, meanwhile, there will arise neither peril nor error from this course, and that I cannot for the present yield too much to distrust, since the end I now seek is not action but knowledge.

I will suppose, then, not that Deity, who is sovereignly good and the fountain of truth, but that some malignant demon, who is at once exceedingly potent and deceitful, has employed all his artifice to deceive me; I will suppose that the sky, the air, the earth, colours, figures, sounds, and all external things, are nothing better than illusions of dreams, by means of which this being has laid snares for my credulity; I will consider myself as without hands, eyes, flesh, blood, or any of the senses, and as falsely believing that I am possessed of these; I will continue resolutely fixed in this belief, and if indeed by this means it be not in my power to arrive at the knowledge of truth, I shall at least do what is in my power, viz., [suspend my judgment], and guard with settled purpose against giving my assent to what is false, and being imposed upon by this deceiver, whatever be his power and artifice.

But this undertaking is arduous, and a certain indolence insensibly leads me back to my ordinary course of life; and just as the captive, who, perchance, was enjoying in his dreams an imaginary liberty, when he begins to suspect that it is but a vision, dreads awakening, and conspires with the agreeable illusions that the deception may be prolonged, so I, of my own accord, fall back into the train of my former beliefs, and fear to arouse myself from my slumber, lest the time of laborious wakefulness that would succeed this quiet rest, in place of bringing any light of day, should prove inadequate to dispel the darkness that will arise from the difficulties that have now been raised.

Meditation II.

OF THE NATURE OF THE HUMAN MIND; AND THAT IT IS MORE EASILY KNOWN THAN THE BODY

The Meditation of yesterday has filled my mind with so many doubts, that it is no longer in my power to forget them. Nor do I see, meanwhile, any principle on which they can be resolved; and just as if I had fallen all of a sudden into very deep water, I am so greatly disconcerted as to be unable either to plant my feet firmly on the bottom or sustain myself by swimming on the surface. I will, nevertheless, make an effort, and try anew the same path on which I had entered yesterday, that is, proceed by casting aside all that admits of the slightest doubt, not less than if I had discovered it to be absolutely false; and I will continue always in this track until I shall find something that is certain, or at least, if I can do nothing more, until I shall know with certainty that there is nothing certain. Archimedes, that he might transport the entire globe from the place it occupied to another, demanded only a point that was firm and immoveable; so also, I shall be entitled to entertain the highest expectations, if I am fortunate enough to discover only one thing that is certain and indubitable.

I suppose accordingly, that all the things which I see are false (fictitious); I believe that none of those objects which my fallacious memory represents ever existed; I suppose that I possess no senses; I believe that body, figure, extension, motion, and place are merely fictions of my mind. What is there, then, that can be esteemed true? Perhaps this only, that there is absolutely nothing certain.

But how do I know that there is not something different altogether from the objects I have now enumerated, of which it is impossible to entertain the slightest doubt? Is there not a God, or some being, by whatever name I may designate him, who causes these thoughts to arise in my mind? But why suppose such a being, for it may be I myself am capable of producing them? Am I then, at least not something? But I before denied that I possessed senses or a body; I hesitate, however, for what follows from that? Am I so dependent on the body and the senses that without these I cannot exist? But I had the persuasion that there was absolutely nothing in the world, that there was no sky, no earth, neither minds nor bodies; was I not therefore, at the same time, persuaded that I did not exist? Far from it; I assuredly existed, since I was persuaded. But there is I know not what being, who is possessed at once of the highest power and the deepest cunning, who is constantly employing all his ingenuity in deceiving me. Doubtless, then, I exist, since I am deceived; and, let him deceive me as he may, he can never bring it about that I am nothing, so long as I shall be conscious that I am something. So that it must, in fine, be maintained, all things being maturely and carefully considered, that this proposition (*pronunciatum*) I am, I exist, is necessarily true each time it is expressed by me, or conceived in my mind.

But I do not yet know with sufficient clearness what I am, though assured that I am; and hence, in the next place, I must take care, lest perchance I inconsiderately substitute some other object in room of what is properly myself, and thus wander from truth, even in that knowledge (cognition) which I hold to be one of all others the most certain and evident. For this reason, I will now consider anew what I formerly believed myself to be, before I entered on the present train of thought; and of my previous opinion I will retrench all that can in the least be invalidated by the grounds of doubt I have adduced, in order that there may at length remain nothing but what is certain and indubitable. What then did I formerly think I was? Undoubtedly I judged that I was a man. But what is a man? Shall I say a rational animal? Assuredly not; for it would be necessary forthwith to inquire into what is meant by an animal, and what by rational, and thus from a single question, I should insensibly glide into others, and these more difficult than the first; nor do I now possess enough of leisure to warrant me in wasting my time amid subtleties of this sort. I prefer here to attend to the thoughts that sprung up of themselves in my mind, and were inspired by my own nature alone, when I applied myself to the consideration of what I was. In the first place, then, I thought that I possessed a countenance, hands, arms, and all the fabric of members that appears in a corpse, and which I called by the name of a body. It further occurred to me that I was nourished, that I walked, perceived, and thought, and all those actions I referred to the soul; but what the soul itself was I either did not stay to consider, or, if I did, I imagined that it was something extremely rare and subtle, like wind, or flame, or ether, spread through my grosser parts. As regarded the body, I did not even doubt of its nature, but thought I distinctly knew it, and if I had wished to describe it according to the notions I then entertained, I should have explained myself in this manner: By body I understand all that can be terminated by a certain figure; that can be comprised in a certain space and so fill a certain space as therefrom to exclude every other body; that can be perceived either by the touch, sight, hearing, taste, or smell; but by something foreign to it by which it is touched [and from which it receives the impression]: for the power of self-motion, as likewise that of perceiving and thinking, I hold as by no means pertaining to the nature of body; on the contrary, I was somewhat astonished to find such faculties existing in some bodies.

But [as to myself, what can I now say that I am], since I suppose there exists an extremely powerful, and, if I may so speak, malignant being, whose whole endeavors are directed towards deceiving me? Can I affirm that I possess any one of all these attributes of which I have lately spoken as belonging to the nature of a body? After attentively considering them in my own mind, I find none of them that can properly be said to belong to myself. To recount them were idle and tedious. Let us pass then to the attributes of the soul. The first mentioned were the powers of nutrition and walking; but, if it be true that I have no body, it is true likewise that I am capable neither of walking nor of being nourished. Perception is another attribute of the soul; but perception too is impossible without the body; besides, I have frequently, during sleep, believed that I perceived objects which I afterwards observed that I did not in reality perceive. Thinking is another attribute of the soul; and here I discover what properly belongs to myself. This alone is inseparable from me. I am—I exist: this is certain; but how often? As often as I think; for perhaps it would even happen, if I should wholly cease to think, that I should at the same time altogether cease to be. I now admit nothing that is not necessarily true: I am therefore, precisely speaking, only a thinking thing, that is, a mind (*mens sive animus*), understanding or reason,—terms whose signification was before unknown to me. I am, however a real thing, and really existent; but what thing? The answer was, a thinking thing. The question now arises, am I aught besides? I will stimulate my imagination with a view to discover whether I am not still something more than a thinking being. Now it is plain I am not the assemblage of members called the human body; I am not a thin and penetrating air diffused through all these members, or flame, or vapour, or breath, or any of all the things I can imagine; for I supposed that all these were not, and, without changing the supposition, I find that I still feel assured of my existence.

But it is true, perhaps, that those very things which I suppose to be non-existent, because they are unknown to me, are not in truth different from myself whom I know. This is a point I cannot determine, and do not now enter into any dispute regarding it. I can only judge of things that are known to me; I am conscious that I exist, and I who know that I exist inquire into who I am. It is, however, perfectly certain that the knowledge of my existence, thus precisely taken, is not dependent on things, the existence of which is as yet unknown to me: and consequently it is not dependent on any of the things I can feign in imagination. Moreover, the phrase itself, I frame an image (*effingo*), reminds me of my error; for I should in truth frame one if I were to imagine myself to be anything, since to imagine is nothing more than to contemplate the figure or image of a corporeal thing; but I already know that I exist, and that it is possible at the same time that all those images, and in general all that relates to the nature of body, are merely dreams [or chimeras]. From this I discover that it is not more reasonable to say, I will excite my imagination that I may know more distinctly what I am, than to express myself as follows: I am now awake, and perceive something real; but because my perception is not sufficiently clear, I will of express purpose go to sleep that my dreams may represent to me the object of my perception with more truth and clearness. And, therefore, I know that nothing of all that I can embrace in imagination belongs to the knowledge which I have of myself, and that there is need to recall with the utmost care the mind from this mode of thinking, that it may be able to know its own nature with perfect distinctness.

But what then am I? A thinking thing, it has been said. But what is a thinking thing? It is a thing that doubts, understands, [conceives], affirms, denies, wills, refuses, that imagines also, and perceives. Assuredly it is not little, if all these properties belong to my nature. But why should they not belong to it? Am I not that very being who now doubts of almost everything; who, for all that, understands and conceives certain things; who affirms one alone as true, and denies the others; who desires to know more of them, and does not wish to be deceived; who imagines many things, sometimes even despite his will; and is likewise percipient of many, as if through the medium of the senses. Is there nothing of all this as true as that I am, even though I should be always dreaming, and although he who gave me being employed all his ingenuity to deceive me? Is there also any one of these attributes that can be properly distinguished from my thought, or that can be said to be separate from myself? For it is of itself so evident that it is I who doubt, I who understand, and I who desire, that it is here unnecessary to add anything by way of rendering it more clear. And I am as certainly the same being who imagines; for, although it may be (as I before supposed) that nothing I imagine is true, still the power of imagination does not cease really to exist in me and to form part of my thought. In fine, I am the same being who perceives, that is, who apprehends certain objects as by the organs of sense, since, in truth, I see light, hear a noise, and feel heat. But it will be said that these presentations are false, and that I am dreaming. Let it be so. At all events it is certain that I seem to see light, hear a noise, and feel heat; this cannot be false, and this is what in me is properly called perceiving (*sentire*), which is nothing else than thinking. From this I begin to know what I am with somewhat greater clearness and distinctness than heretofore.

But, nevertheless, it still seems to me, that I cannot help believing, that corporeal things, whose images are formed by thought, [which fall under the senses], and are examined by the same, are known with much greater distinctness than that I know not what part of myself which is not imaginable; although in truth, it may seem strange to say that I know and comprehend with greater distinctness things whose existence appears to me doubtful, that are unknown, and do not belong to me, than others of whose reality I am persuaded, that are known to me, and appertain to my proper nature; in a word, than myself. But I see clearly what is the state of the case. My mind is apt to wander, and will not yet submit to be restrained within the limits of truth. Let us therefore leave the mind to itself once more, and, according to it every kind of liberty, [permit it to consider the objects that appear to it from without], in order that, having afterwards withdrawn it from these gently and opportunely, [and fixed it on the consideration of its being and the properties it finds in itself], it may then be the more easily controlled.

Let us now accordingly consider the objects that are commonly thought to be [the most easily, and likewise], the most distinctly known, viz., the bodies we touch and see; not, indeed, bodies in general, for these general notions are usually somewhat more confused, but one body in particular. Take, for example, this piece of wax; it is quite fresh, having been but recently taken from the bee-hive; it has not yet lost the sweetness of the honey it contained; it still retains somewhat of the odour of the flowers from which it was gathered; its colour, figure, size, are apparent (to the sight); it is hard, cold, easily handled; and sounds when struck upon with the finger. In fine, all that contributes to make a body as distinctly known as possible, is found in the one before us. But, while I am speaking, let it be placed near the fire—what remained of the taste exhales, the smell evaporates, the colour changes, its figure is destroyed, its size increases it becomes a liquid, it grows hot, it can hardly be handled, and, although struck upon, it emits no sound. Does the same wax still remain after this change? It must be admitted that it does remain; no one doubts it or judges otherwise. What, then, was it I knew with so much distinctness in the piece of wax? Assuredly, it could be nothing at all that I observed by means of the senses, since all the things that fell under taste, smell, sight, touch, and hearing are changed, and yet the same wax remains. It was perhaps what I now think, viz., that this wax was neither the sweetness of honey, the pleasant odour of flowers, the whiteness, the figure, nor the sound, but only a body that a little before appeared to me conspicuous under these forms, and which is now perceived under others. But, to speak precisely, what is it that I imagine when I think of it in this way? Let it be attentively considered, and, retrenching all that does not belong to the wax, let us see what remains. There certainly remains nothing, except something extended, flexible and moveable. But what is meant by flexible and moveable? Is it not that I imagine that the piece of wax, being round, is capable of becoming square, or of passing from a square into a triangular figure? Assuredly such is not the case, because I conceive that it admits of an infinite variety of similar changes; and I am, moreover, unable to compass this infinity by imagination, and consequently this conception which I have of the wax is not the product of the faculty of imagination. But what now of this extension? Is it not also unknown? for it becomes greater when the wax is melted, greater when it is boiled, and greater still when the heat increases; and I should not conceive [clearly and] according to the truth, the wax as it is, if I did not suppose that the piece we are considering admitted even of a wider variety of extension than I ever imagined. I must, therefore, admit that I cannot even comprehend by imagination what the piece of wax is, and that it is the mind alone (*mens* Lat., *entendement*, F.) which perceives it. I speak of one piece in particular; for, as to wax in general, this is still more evident. But what is the piece of wax that can be perceived only by the [understanding or] mind? It is certainly the same which I see, touch, imagine; and, in fine, it is the same which, from the beginning I believed it to be. But (and this it is of moment to observe) the perception of it is neither an act of sight, of touch, nor of imagination, and never was either of these, though it might formerly seem so, but is simply an intuition (*inspectio*) of the mind, which may be imperfect and confused, as it formerly was, or very clear and distinct, as it is at present, according as the attention is more or less directed to the elements which it contains, and of which it is composed.

But, meanwhile, I feel greatly astonished when I observe [the weakness of my mind, and] its proneness to error. For although, without at all giving expression to what I think, I consider all this in my own mind, words yet occasionally impede my progress, and I am almost led into error by the terms of ordinary language. We say, for example, that we see the same wax when it is before us, and not that we judge it to be the same from its retaining the same colour and figure; whence I should forthwith be disposed to conclude that the wax is known by the act of sight, and not by the intuition of the mind alone, were it not for the analogous instance of human beings passing on in the street below, as observed from a window. In this case I do not fail to say that I see the men themselves, just as I say that I see the wax; and yet what do I see from the window beyond hats and cloaks that might cover artificial machines, whose motions might be determined by springs? But I judge that there are human beings from these appearances, and thus I comprehend, by the faculty of judgment alone which is in the mind, what I believed I saw with my eyes.

The man who makes it his aim to rise to knowledge superior to the common, ought to be ashamed to seek occasions of doubting from the vulgar forms of speech: instead, therefore, of doing this, I shall proceed with the matter in hand, and inquire whether I had a clearer and more perfect perception of the piece of wax when I first saw it, and when I thought I knew it by means of the external sense itself, or, at all events, by the common sense (*sensus communis*), as it is called, that is by the imaginative faculty; or whether I rather apprehend it more clearly at present, after having examined with greater care, both what it is, and in what way it can be known. It would certainly be ridiculous to entertain any doubt on this point. For what, in that first perception, was there distinct? What did I perceive which any animal might not have perceived? But when I distinguish from the exterior forms, and when, as if I had stripped it of its vestments, I consider it quite naked, it is certain, although some error may still be found in my judgment, that I cannot, nevertheless, thus apprehend it without possessing a human mind.

But, finally, what shall I say of the mind itself, that is, of myself? for as yet I do not admit that I am anything but mind. What then! I who seem to possess so distinct an apprehension of the piece of wax,—do I not know myself, both with greater truth and certitude, and also much more distinctly and clearly? For if I judge that the wax exists because I see it, it assuredly follows, much more evidently, that I myself am or exist, for the same reason; for it is possible that what I see may not in truth be wax, and that I do not even possess eyes with which to see anything; but it cannot be that when I see, or, which comes to the same thing, when I think I see, I myself who think am nothing. So likewise, if I judge that the wax exists because I touch it, it will still also follow that I am; and if I determine that my imagination, or any other cause, whether it be, persuades me of the existence of wax, I will still draw the same conclusion. And what is here remarked of the piece of wax, is applicable to all the other things that are external to me. And further, if the [notion or] perception of wax appeared to me more precise and distinct, after that not only sight and touch, but many other causes besides, rendered it manifest to my apprehension, with how much greater distinctness must I now know myself, since all the reasons that contribute to the nature of wax, or of any other body whatever, manifest still better the nature of my mind? And there are besides so many other things in the mind itself that contribute to the illustration of its nature, that those dependent on the body, to which I have here referred, scarcely merit to be taken into account.

But, in conclusion, I find I have insensibly reverted to the point I desired; for, since it is now manifest to me that bodies themselves are not properly perceived by the senses nor by the faculty of imagination, but by the intellect alone; and since they are not perceived because they are seen and touched, but only because they are understood [or rightly comprehended by thought], I readily discover that there is nothing more easily or clearly apprehended than my own mind. But because it is difficult to rid one's self so promptly of an opinion to which one has been long accustomed, it will be desirable to tarry for some time at this stage, that, by long continued meditation, I may more deeply impress upon my memory this new knowledge.

MEDITATION III.

OF GOD

With reference to these ideas of corporeal things that are clear and distinct, there are some which, as appears to me, might have been taken from the idea I have of myself, as those of substance, duration, number, and the like. For when I think that a stone is a substance, although I conceive that I am a thinking and non-extended thing, and that the stone, on the contrary, is extended and unconscious, there being thus the greatest diversity between the two concepts,—yet these two ideas seem to have this in common that they both represent substances. In the same way, when I think of myself as now existing, and recollect besides that I existed sometime ago, and when I am conscious of various thoughts whose number I know, I then acquire the ideas of duration and number, which I can afterwards transfer to as many objects as I please. With respect to the other qualities that go to make up the ideas of corporeal objects, viz., extension, figure, situation, motion, it is true that they are not formally in me, since I am merely a thinking being; but because they are only certain modes of substance, and because I myself am a substance, it seems possible that they may be contained in me eminently.

There only remains, therefore, the idea of God, in which I must consider whether there is anything that cannot be supposed to originate with myself. By the name God, I understand a substance infinite, [eternal, immutable], independent, all-knowing, all-powerful, and by which I myself, and every other thing that exists, if any such there be, were created. But these properties are so great and excellent, that the more attentively I consider them the less I feel persuaded that the idea I have of them owes its origin to myself alone. And thus it is absolutely necessary to conclude, from all that I have before said, that God exists: for though the idea of substance be in my mind owing to this, that I myself am a substance, I should not, however, have the idea of an infinite substance, seeing I am a finite being, unless it were given me by a substance in reality infinite.

And I must not imagine that I do not apprehend the infinite by a true idea, but only by a negation of the infinite, in the same way that I comprehend repose and darkness by the negation of motion and light: since, on the contrary, I clearly perceive that there is more reality in the infinite substance than in the finite, and therefore that in some way I possess the perception (notion) of the infinite before that of the finite, that is, the perception of God before that of myself, for how could I know that I doubt, desire, or that something is wanting to me, and that I am not wholly perfect, if I possessed no idea of a being more perfect than myself, by comparison of which I knew the deficiencies of my nature?

And it cannot be said that this idea of God is perhaps materially false, and consequently that it may have arisen from nothing, [in other words, that it may exist in me from my imperfection], as I before said of the ideas of heat and cold, and the like: for, on the contrary, as this idea is very clear and distinct, and contains in itself more objective reality than any other, there can be no one of itself more true, or less open to the suspicion of falsity.

The idea, I say, of a being supremely perfect, and infinite, is in the highest degree true; for, although, perhaps, we may imagine that such a being does not exist, we cannot, nevertheless, suppose that his idea represents nothing real, as I have already said of the idea of cold. It is likewise clear and distinct in the highest degree, since whatever the mind clearly and distinctly conceives as real or true, and as implying any perfection, is contained entire in this idea. And this is true, nevertheless, although I do not comprehend the infinite, although there may be in God an infinity of things that I cannot comprehend, nor perhaps even compass by thought in any way; for it is of the nature of the infinite that it should not be comprehended by the finite; and it is enough that I rightly understand this, and judge that all which I clearly perceive, and in which I know there is some perfection, and perhaps also an infinity of properties of which I am ignorant, are formally or eminently in God, in order that the idea I have of him may become the most true, clear, and distinct of all the ideas in my mind.

But perhaps I am something more than I suppose myself to be, and it may be that all those perfections which I attribute to God, in some way exist potentially in me, although they do not yet show themselves, and are not reduced to act. Indeed, I am already conscious that my knowledge is being increased [and perfected] by degrees; and I see nothing to prevent it from thus gradually increasing to infinity, nor any reason why, after such increase and perfection, I should not be able thereby to acquire all the other perfections of the Divine nature; nor, in fine, why the power I possess of acquiring those perfections, if it really now exist in me, should not be sufficient to produce the ideas of them. Yet, on looking more closely into the matter, I discover that this cannot be; for in the first place, although it were true that my knowledge daily acquired new degrees of perfection, and although there were potentially in my nature much that was not as yet actually in it, still all these excellencies make not the slightest approach to the idea I have of the Deity, in whom there is no perfection merely potentially [but all actually] existent; for it is even an unmistakable token of imperfection in my knowledge, that it is augmented by degrees. Further, although my knowledge increase more and more, nevertheless I am not, therefore, induced to think that it will ever be actually infinite, since it can never reach that point beyond which it shall be incapable of further increase. But I conceive God as actually infinite, so that nothing can add to his perfection. And, in fine, I readily perceive that the objective being of an idea cannot be produced by a being that is merely potentially existent, which, properly speaking, is nothing, but only by a being existent formally or actually.

And, truly, I see nothing in all that I have now said which it is not easy for any one, who shall carefully consider it, to discern the natural light; but when I allow my attention in some degree to relax, the vision of my mind being obscured, and, as it were, blinded by the images of sensible objects, I do not readily remember the reason why the idea of a being more perfect than myself, must of necessity have proceeded from a being in reality more perfect. On this account I am here desirous to inquire further, whether I, who possess this idea of God, could exist supposing there were no God. And I ask, from whom could I, in that case, derive my existence? Perhaps from myself, or from my parents, or from some other causes less perfect than God; for anything more perfect, or even equal to God, cannot be thought or imagined. But if I [were independent of every other existence, and] were myself the author of my being, I should doubt of nothing, and, in fine, no perfection would be wanting to me; for I should have bestowed upon myself every perfection of which I possess the idea, and I should thus be God. And it must not be imagined that what is now wanting to me is perhaps of more difficult acquisition than that of which I am already possessed; for, on the contrary, it is quite manifest that it was a matter of much higher difficulty that I, a thinking being, should arise from nothing, than it would be for me to acquire the knowledge of many things of which I am ignorant, and which are merely the accidents of a thinking substance; and certainly, if I possessed of myself the greater perfection of which I have now spoken, [in other words, if I were the author of my own existence], I would not at least have denied to myself things that may be more easily obtained, [as that infinite variety of knowledge of which I am at present destitute]. I could not, indeed, have denied myself any property which I perceive is contained in the idea of God, because there is none of these that seems to me to be more difficult to make or acquire; and if there were any that should happen to be more difficult to acquire, they would certainly appear so to me (supposing that I myself were the source of the other things I possess), because I should discover in them a limit to my power. And though I were to suppose that I always was as I now am, I should not, on this ground, escape the force of these reasonings, since it would not follow, even on this supposition, that no author of my existence needed to be sought after. For the whole of my life may be divided into an infinity of parts, each of which is in no way dependent on any other; and, accordingly, because I was in existence a short time ago, it does not follow that I must now exist, unless in this moment some cause create me anew, as it were,—that is, conserve me. In truth, it is perfectly clear and evident to all who will attentively consider the nature of duration, that the conservation of a substance, in each moment of its duration, requires the same power and act that would be necessary to create it, supposing it were not yet in existence; so that it is manifestly a dictate of the natural light that conservation and creation differ merely in respect of our mode of thinking [and not in reality]. All that is here required, therefore, is that I interrogate myself to discover whether I possess any power by means of which I can bring it about that I, who now am, shall exist a moment afterwards; for, since I am merely a thinking thing (or since, at least, the precise question, in the meantime, is only of that part of myself), if such a power resided in me, I should, without doubt, be conscious of it; but I am conscious of no such power, and thereby I manifestly know that I am dependent upon some being different from myself.

But perhaps the being upon whom I am dependent, is not God, and I have been produced either by my parents, or by some causes less perfect than Deity. This cannot be: for, as I before said, it is perfectly evident that there must at least be as much reality in the cause as in its effect; and accordingly, since I am a thinking thing, and possess in myself an idea of God, whatever in the end be the cause of my existence, it must of necessity be admitted that it is likewise a thinking being, and that it possesses in itself the idea and all the perfections I attribute to Deity. Then it may again be inquired whether this cause owes its origin and existence to itself, or to some other cause. For if it be self-existent, it follows, from what I have before laid down, that this cause is God; for since it possesses the perfection of self-existence, it must likewise, without doubt, have the power of actually possessing every perfection of which it has the idea,—in other words, all the perfections I conceive to belong to God. But if it owes its existence to another cause than itself, we demand again, for a similar reason, whether this second cause exists of itself or through some other, until, from stage to stage, we at length arrive at an ultimate cause, which will be God. And it is quite manifest that in this matter there can be no infinite regress of causes, seeing that the question raised respects not so much the cause which once produced me, as that by which I am this moment conserved.

Nor can it be supposed that several causes concurred in my production, and that from one I received the idea of one of the perfections I attribute to Deity, and from another the idea of some other, and thus that all those perfections are indeed found somewhere in the universe, but do not all exist together in a single being who is God; for, on the contrary, the unity, the simplicity or inseparability of all the properties of Deity, is one of the chief perfections I conceive him to possess; and the idea of this unity of all the perfections of Deity could certainly not be put into my mind by any cause from which I did not likewise receive the ideas of all the other perfections; for no power could enable me to embrace them in an inseparable unity, without at the same time giving me the knowledge of what they were [and of their existence in a particular mode].

Finally, with regard to my parents [from whom it appears I sprung], although all that I believed respecting them be true, it does not, nevertheless, follow that I am conserved by them, or even that I was produced by them, in so far as I am a thinking being. All that, at the most, they contributed to my origin was the giving of certain dispositions (modifications) to the matter in which I have hitherto judged that I or my mind, which is what alone I now consider to be myself, is enclosed; and thus there can here be no difficulty with respect to them, and it is absolutely necessary to conclude from this alone that I am, and possess the idea of a being absolutely perfect, that is, of God, that his existence is most clearly demonstrated.

There remains only the inquiry as to the way in which I received this idea from God; for I have not drawn it from the senses, nor is it even presented to me unexpectedly, as is usual with the ideas of sensible objects, when these are presented, or appear to be presented to the external organs of the senses; it is not even a pure production or fiction of my mind, for it is not in my power to take from or add to it; and consequently there remains the same alternative that is innate, in the same way as is the idea of myself. And, in truth, it is not to be wondered that God, at my creation, implanted this idea in me, that it might serve, as it were, for the mark of the workman impressed on his work; and it is not also necessary that the mark should be something different from the work itself; but considering only that God is my creator, it is highly probable that he in some way fashioned me after his own likeness, in which is contained the idea of God, by the same faculty by which I apprehend myself,—in other words, when I make myself the object of reflection, I not only find that I am an incomplete, [imperfect] and dependent being, and one who unceasingly aspires after something better and greater than he is; but, at the same time, I am assured likewise that he upon whom I am dependent possesses in himself all the goods after which I aspire, [and the ideas of him which I find in my mind], and that not merely indefinitely and potentially, but infinitely and actually, and that he is thus God. And the whole force of the argument of which I have here availed myself to establish the existence of God, consists in this, that I perceive I could not possibly be of such a nature as I am, and yet have in my mind the idea of a God, if God did not in reality exist,—this same God, I say, whose idea is in my mind—that is, a being who possesses all those lofty perfections, of which the mind may have some slight conception, without, however, being able fully to comprehend them,—and who is wholly superior to all defect, [and has nothing that marks imperfection]: whence it is sufficiently manifest that he cannot be a deceiver, since it is a dictate of the natural light that all fraud and deception spring from defect.

But before I examine this with more attention, and pass on to the consideration of other truths that may be evolved out of it, I think it proper to remain here for some time in the contemplation of God himself—that I may ponder at leisure his marvellous attributes—and behold, admire and adore the beauty of this light so unspeakably great, as far, at least, as the strength of my mind, which is to some degree dazzled by the sight, will permit. For just as we learn by faith that the supreme felicity of another life consists in the contemplation of the Divine majesty alone, so even now we learn from experience that a like meditation, though incomparably less perfect, is the source of the highest satisfaction of which we are susceptible in this life.

MEDITATION IV.

OF TRUTH AND ERROR

TRUTH DEPENDENT ON GOD

I have been habituated these bygone days to detach my mind from the senses, and I have accurately observed that there is exceedingly little which is known with certainty respecting corporeal objects,—that we know much more of the human mind, and still more of God Himself. I am thus able now without difficulty to abstract my mind from the contemplation of [sensible or] imaginable objects, and apply it to those which, as disengaged from all other matter, are purely intelligible. And certainly the idea I have of the human mind, in so far as it is a thinking thing, and not extended in length, breadth, and depth, and participating in none of the properties of body, is incomparably more distinct than the idea of any corporeal object; and when I consider that I doubt, in other words, that I am an incomplete and dependent being, the idea of a complete and independent being, that is to say of God, occurs to my mind with so much distinctness and clearness,—and from the fact alone that this idea is found in me, or that I who possess it exist, the conclusions that God exists, and that my own existence, each moment of its continuance, is absolutely dependent upon Him, are so manifest,—as to lead me to believe it impossible that the human mind can know anything with more clearness and certitude. And now I seem to discover a path that will conduct us from the contemplation of the true God, in whom are contained all the treasures of science and wisdom, to the knowledge of the other things in the universe.

For, in the first place, I discover that it is impossible for Him ever to deceive me, for in all fraud and deceit there is a certain imperfection; and although it may seem that the ability to deceive is a mark of subtlety or power, yet the will testifies without doubt of malice and weakness; and such, accordingly cannot be found in God. In the next place, I am conscious that I possess a certain faculty of judging [or discerning truth from error], which I doubtless received from God, along with whatever else is mine; and since it is impossible that He should will to deceive me, it is likewise certain that He has not given me a faculty that will ever lead me into error, provided I use it aright.

And there would remain no doubt on this head, did it not seem to follow from this, that I can never therefore be deceived; for if all I possess be from God, and if He planted in me no faculty that is deceitful, it seems to follow that I can never fall into error. Accordingly, it is true that when I think only of God (when I look upon myself as coming from God,) and turn wholly to Him, I discover [in myself] no cause of error or falsity; but immediately thereafter, recurring to myself, experience assures me that I am nevertheless subject to innumerable errors. When I come to inquire into the cause of these, I observe that there is not only present to my consciousness a real and positive idea of God, or of a being supremely perfect, but also, so to speak, a certain negative idea of nothing,—in other words, of that which is at an infinite distance from every sort of perfection, and that I am, as it were, a mean between God and nothing, or placed in such a way between the absolute existence and non-existence, that there is in truth nothing in me to lead me into error, in so far as an absolute being is my creator; but that, on the other hand, as I thus likewise participate in some degree of nothing or of non-being, in other words, as I am not myself the supreme Being, and as I am wanting in many perfections, it is not surprising I should fall into error. And I hence discern that error is not something real, which depends for its existence on God, but is simply defect; and therefore that, in order to fall into it, it is not necessary that God should have given me a faculty expressly for this end, but that my being deceived arises from the circumstances that the power which God has given me of discerning truth from error is not infinite.

SPINOZA

Benedict Spinoza was born of a Jewish family in Amsterdam in the year 1632. He got his first schooling under Rabbi Morteira. He also learned to polish lenses. Later he struck up a friendship with Jorigh Jelles, an Anabaptist, and made something of a study of Christianity. He became interested in the treasures of knowledge enclosed in Latin and some of the modern languages, and grew to be something of a linguist. The new physical sciences also interested him, and at last he was attracted by philosophy. His opinions brought him into conflict with the Jewish community in which he lived, and he was expelled from the synagogue.

The philosophy of the time was that of Descartes. This looked at the material world as purely mechanical, and placed an absolute gulf, bridged only by God, between matter and mind. Spinoza gradually came to look back of this dualism, and to consider God or Nature the only true reality and all else but manifestations of this. Matter and mind are two attributes of God. They are always found together, not interacting, but parallel, two expressions of the same truth.

All his life was passed in Holland, and was mostly a solitary existence, occupied in his lens-polishing, his meditations and his correspondence. He became a man of prominence, and was offered (1673) a professorship but declined it. He died February 21, 1677.

THE ETHICS

PART I. CONCERNING GOD

DEFINITIONS

I. By that which is self-caused, I mean that of which the essence involves existence, or that of which the nature is only conceivable as existent.

II. A thing is called finite after its kind, when it can be limited by another thing of the same nature; for instance, a body is called finite because we always conceive another greater body. So, also, a thought is limited by another thought, but a body is not limited by thought, nor a thought by body.

III. By substance, I mean that which is in itself, and is conceived through itself; in other words, that of which a conception can be formed independently of any other conception.

IV. By attribute, I mean that which the intellect perceives as constituting the essence of substance.

V. By mode, I mean the modifications of substance, or that which exists in, and is perceived through, something other than itself.

VI. By God, I mean a being absolutely infinite—that is, a substance consisting in infinite attributes, of which each expresses eternal and infinite essentiality.

Explanation.—I say absolutely infinite, not infinite after its kind; for, of a thing infinite only after its kind, infinite attributes may be denied; but that which is absolutely infinite, contains in its essence whatever expresses reality, and involves no negation.

VII. That thing is called free, which exists solely by the exist in the universe (for simplicity's sake, I will suppose them existing simultaneously, and to have had no predecessors), and we want to account for the existence of these twenty men, it will not be enough to show the cause of human existence in general; we must also show why there are exactly twenty men, neither more nor less: for a cause must be assigned for the existence of each individual. Now this cause cannot be contained in the actual nature of man, for the true definition of man does not involve any consideration of the number twenty. Consequently, the cause for the existence of these twenty men, and, consequently, of each of them, must necessarily be sought externally to each individual. Hence we may lay down the absolute rule, that everything which may consist of several individuals must have an external cause. And, as it has been shown already that existence appertains to the nature of substance, existence must necessarily be included in its definition; and from its definition alone existence must be deductible. But from its definition (as we have shown, Notes ii., iii.), we cannot infer the existence of several substances; therefore it follows that there is only one substance of the same nature. Q. E. D.

Prop. IX. The more reality or being a thing has the greater the number of its attributes (Def. iv.).

Prop. X. Each particular attribute of the one substance must be conceived through itself.

Proof.—An attribute is that which the intellect perceives of substance, as though constituting its essence (Def. iv.), and, therefore, must be conceived through itself (Def. iii.). Q. E. D.

Note.—It is thus evident that, though two attributes are, in fact, conceived as distinct—that is, one without the help of the other—yet we cannot, therefore, conclude that they constitute two entities, or two different substances. For it is the nature of substance that each of its attributes is conceived through itself, inasmuch as all the attributes it has have always existed simultaneously in it, and none could be produced by any other; but each expresses the reality or being of substance. It is, then, far from an absurdity to ascribe several attributes to one substance: for nothing in nature is more clear than that each and every entity must be conceived under some attribute, and that its reality or being is in proportion to the number of its attributes expressing necessity or eternity and infinity. Consequently it is abundantly clear, than an absolutely infinite being must necessarily be defined as consisting in infinite attributes, each of which expresses a certain eternal and infinite essence.

If anyone now ask, by what sign shall he be able to distinguish different substances, let him read the following propositions, which show that there is but one substance in the universe, and that it is absolutely infinite, wherefore such a sign would be sought for in vain.

Prop. XI. God, or substance, consisting of infinite attributes, of which each expresses eternal and infinite essentiality, necessarily exists.

Proof.—If this be denied, conceive, if possible, that God does not exist: then his essence does not involve existence. But this (by Prop. vii.) is absurd. Therefore God necessarily exists.

Another Proof.—Of everything whatsoever a cause or reason must be assigned, either for its existence, or for its non-existence—e. g., if a triangle exist, a reason or cause must be granted for its existence; if, on the contrary, it does not exist, a cause must also be granted, which prevents it from existing, or annuls its existence. This reason or cause must either be contained in the nature of the thing in question, or be external to it. For instance, the reason for the non-existence of a square circle is indicated in its nature, namely, because it would involve a contradiction. On the other hand, the existence of substance follows also solely from its nature, inasmuch as its nature involves existence. (See Prop. vii.)

But the reason for the existence of a triangle or a circle does not follow from the nature of those figures, but from the order of universal nature in extension. From the latter it must follow, either that a triangle necessarily exists, or that it is impossible that it should exist. So much is self-evident. It follows therefrom that a thing necessarily exists, if no cause or reason be granted which prevents its existence.

If, then, no cause or reason can be given, which prevents the existence of God, or which destroys his existence, we must certainly conclude that he necessarily does exist. If such a reason or cause should be given, it must either be drawn from the very nature of God, or be external to him—that is, drawn from another substance of another nature. For if it were of the same nature, God, by that very fact, would be admitted to exist. But substance of another nature could have nothing in common with God (by Prop. ii.), and therefore would be unable either to cause or to destroy his existence.

As, then, a reason or cause which would annul the divine existence cannot be drawn from anything external to the divine nature, such cause must perforce, if God does not exist, be drawn from God's own nature, which would involve a contradiction. To make such an affirmation about a being absolutely infinite and supremely perfect, is absurd; therefore, neither in the nature of God, nor externally to his nature, can a cause or reason be assigned which would annul his existence. Therefore, God necessarily exists. Q. E. D.

Another Proof.—The potentiality of non-existence is a negation of power, and contrariwise the potentiality of existence is a power, as is obvious. If, then, that which necessarily exists is nothing but finite beings, such finite beings are more powerful than a being absolutely infinite, which is obviously absurd; therefore, either nothing exists, or else a being absolutely infinite necessarily exists also. Now we exist either in ourselves, or in something else which necessarily exists (see Axiom i. and Prop. vii.). Therefore a being absolutely infinite—in other words, God (Def. vi.)—necessarily exists. Q. E. D.

Note.—In this last proof, I have purposely shown God's existence *a posteriori*, so that the proof might be more easily followed, not because, from the same premises, God's existence does not follow *a priori*. For, as the potentiality of existence is a power, it follows that, in proportion as reality increases in the nature of a thing, so also will it increase its strength for existence. Therefore a being absolutely infinite, such as God, has from himself an absolutely infinite power of existence, and hence he does absolutely exist. Perhaps there will be many who will be unable to see the force of this proof, inasmuch as they are accustomed only to consider those things which flow from external causes. Of such things, they see that those which quickly come to pass—that is, quickly come into existence—quickly also disappear; whereas they regard as more difficult of accomplishment—that is, not so easily brought into existence—those things which they conceive as more complicated.

However, to do away with this misconception, I need not here show the measure of truth in the proverb, "What comes quickly, goes quickly," nor discuss whether, from the point of view of universal nature, all things are equally easy, or otherwise: I need only remark, that I am not here speaking of things, which come to pass through causes external to themselves, but only of substances which (by Prop. vi.) cannot be produced by any external cause. Things which are produced by external causes whether they consist of many parts or few, owe whatsoever perfection or reality they possess solely to the efficacy of their external cause, and therefore their existence arises solely from the perfection of their external cause, not from their own. Contrariwise, whatsoever perfection is possessed by substance is due to no external cause; wherefore the existence of substance must arise solely from its own nature, which is nothing else but its essentiality. Thus, the perfection of a thing does not annul its existence, but, on the contrary, asserts it. Imperfection, on the other hand, does annul it; therefore we cannot be more certain of the existence of anything, than of the existence of a being absolutely infinite or perfect—that is, of God. For inasmuch as his essence excludes all imperfection, and involves absolute perfection, all cause for doubt concerning his existence is done away, and the utmost certainty on the question is given. This, I think, will be evident to every moderately attentive reader.

Against Misconceptions of God's Nature

Appendix.—In the foregoing I have explained the nature and properties of God. I have shown that he necessarily exists, that he is one: that he is, and acts solely by the necessity of his own nature; that he is the free cause of all things, and how he is so; that all things are in God, and so depend on him, that without him they could neither exist nor be conceived; lastly, that all things are predetermined by God, not through his free will or absolute fiat, but from the very nature of God or infinite power. I have further, where occasion offered, taken care to remove the prejudices, which might impede the comprehension of my demonstrations. Yet there still remain misconceptions not a few, which might and may prove very grave hindrances to the understanding of the concatenation of things, as I have explained it above. I have therefore thought it worth while to bring these misconceptions before the bar of reason.

All such opinions spring from the notion commonly entertained, that all things in nature act as men themselves act, namely, with an end in view. It is accepted as certain, that God himself directs all things to a definite goal (for it is said that God made all things for necessity of its own nature, and of which the action is determined by itself alone. On the other hand, that thing is necessary, or rather constrained, which is determined by something external to itself to a fixed and definite method of existence or action.

VIII. By eternity, I mean existence itself, in so far as it is conceived necessarily to follow solely from the definition of that which is eternal.

Explanation.—Existence of this kind is conceived as an eternal truth, like the essence of a thing, and, therefore, cannot be explained by means of continuance or time, though continuance may be conceived without a beginning or end.

AXIOMS

I. Everything which exists, exists either in itself or in something else.

II. That which cannot be conceived through anything else must be conceived through itself.

III. From a given definite cause an effect necessarily follows; and, on the other hand, if no definite cause be granted, it is impossible that an effect can follow.

IV. The knowledge of an effect depends on and involves the knowledge of a cause.

V. Things which have nothing in common cannot be understood, the one by means of the other; the conception of one does not involve the conception of the other.

VI. A true idea must correspond with its ideate or object.

VII. If a thing can be conceived as non-existing, its essence does not involve existence.

PROPOSITIONS

Prop. I. Substance is by nature prior to its modifications.

Proof.—This is clear from Def. iii. and v.

Prop. II. Two substances, whose attributes are different, have nothing in common.

Proof.—Also evident from Def. iii. For each must exist in itself, and be conceived through itself; in other words, the conception of one does not imply the conception of the other.

Prop. III. Things which have nothing in common cannot be one the cause of the other.

Proof.—If they have nothing in common, it follows that one cannot be apprehended by means of the other (Ax. v.), and, therefore, one cannot be the cause of the other (Ax. iv.) Q. E. D.

Prop. IV. Two or more distinct things are distinguished one from the other, either by the difference of the attributes of the substances, or by the difference of their modifications.

Proof.—Everything which exists, exists either in itself or in something else (Ax. i.),—that is (by Def. iii. and v.), nothing is granted in addition to the understanding, except substance and its modifications. Nothing is, therefore, given besides the understanding, by which several things may be distinguished one from the other, except the substances, or, in other words (see Ax. iv.), their attributes and modifications. Q. E. D.

Prop. V. There cannot exist in the universe two or more substances having the same nature or attribute.

Proof.—If several distinct substances be granted, they must be distinguished one from the other, either by the difference of their attributes, or by the difference of their modifications (Prop. iv.). If only by the difference of their attributes it will be granted that there cannot be more than one, with an identical attribute. If by the difference of their modifications—as substance is naturally prior to its modifications (Prop. i.),—it follows that setting the modifications aside, and considering substance in itself, that is, truly (Def. iii. and vi.), there cannot be conceived one substance different from another,—that is (by Prop. iv.), there cannot be granted several substances, but one substance only. Q. E. D.

Prop. VI. One substance cannot be produced by another substance.

Proof.—It is impossible that there should be in the universe two substances with an identical attribute, i. e., which have anything common to them both (Prop. ii.), and, therefore (Prop. iii.), one cannot be the cause of another, neither can one be produced by the other. Q. E. D.

Corollary.—Hence it follows that a substance cannot be produced by anything external to itself. For in the universe nothing is granted, save substances and their modifications (as appears from Ax. i. and Def. iii. and v.). Now (by the last Prop.) substance cannot be produced by another substance, therefore it cannot be produced by anything external to itself. Q. E. D. This is shown still more readily by the absurdity of the contradictory. For, if substance be produced by an external cause, the knowledge of it would depend on the knowledge of its cause (Ax. iv.), and (by Def. iii.) it would itself not be substance.

Prop. VII. Existence belongs to the nature of substance.

Proof.—Substance cannot be produced by anything external (Corollary, Prop. vi.), it must, therefore, be its own cause—that is, its essence necessarily involves existence, or existence belongs to its nature.

Prop. VIII. Every substance is necessarily infinite.

Proof.—There can only be one substance with an identical attribute, and existence follows from its nature (Prop. vii.); its nature, therefore, involves existence, either as finite or infinite. It does not exist as finite, for (by Def. ii.) it would then be limited by something else of the same kind, which would also necessarily exist (Prop. vii.); and there would be two substances with an identical attribute, which is absurd (Prop. vi.). It therefore exists as infinite. Q. E. D.

Note I.—As finite existence involves a partial negation, and infinite existence is the absolute affirmation of the given nature, it follows (solely from Prop. vii.) that every substance is necessarily infinite.

Note II.—No doubt it will be difficult for those who think about things loosely, and have not been accustomed to know them by their primary causes, to comprehend the demonstration of Prop. vii.: for such persons make no distinction between the modifications of substances and the substances themselves, and are ignorant of the manner in which things are produced; hence they attribute to substances the beginning which they observe in natural objects. Those who are ignorant of true causes, make complete confusion—think that trees might talk just as well as men—that men might be formed from stones as well as from seed; and imagine that any form might be changed into any other. So, also, those who confuse the two natures, divine and human, readily attribute human passions to the Deity, especially so long as they do not know how passions originate in the mind. But, if people would consider the nature of substance, they would have no doubt about the truth of Prop. vii. In fact, this proposition would be a universal axiom, and accounted a truism. For, by substance, would be understood that which is in itself, and is conceived through itself—that is, something of which the conception requires not the conception of anything else; whereas modifications exist in something external to themselves, and a conception of them is formed by means of a conception of the thing in which they exist. Therefore, we may have true ideas of non-existent modifications; for, although they may have no actual existence apart from the conceiving intellect, yet their essence is so involved in something external to themselves that they may through it be conceived. Whereas the only truth substances can have, external to the intellect, must consist in their existence, because they are conceived through themselves. Therefore, for a person to say that he has a clear and distinct—that is, a true—idea of a substance, but that he is not sure whether such substance exists, would be the same as if he said that he had a true idea, but was not sure whether or no it was false (a little consideration will make this plain); or if anyone affirmed that substance is created, it would be the same as saying that a false idea was true—in short, the height of absurdity. It must, then, necessarily be admitted that the existence of substance as its essence is an eternal truth. And we can hence conclude by another process of reasoning—that there is but one such substance. I think that this may profitably be done at once; and, in order to proceed regularly with the demonstration, we must premise:—

1. The true definition of a thing neither involves nor expresses anything beyond the nature of the thing defined. From this it follows that—

2. No definition implies or expresses a certain number of individuals, inasmuch as it expresses nothing beyond the nature of the thing defined. For instance, the definition of a triangle expresses nothing beyond the actual nature of a triangle: it does not imply any fixed number of triangles.

3. There is necessarily for each individual existent thing a cause why it should exist.

4. This cause of existence must either be contained in the nature and definition of the thing defined, or must be postulated apart from such definition.

It therefore follows that, if a given number of individual things exist in nature, there must be some cause for the existence of exactly that number, neither more nor less. For example, if twenty men fer order to confusion—as though there were any order in nature, except in relation to our imagination—and say that God has created all things in order; thus, without knowing it, attributing imagination to God, unless, indeed, they would have it that God foresaw human imagination, and arranged everything, so that it should be most easily imagined. If this be their theory, they would not, perhaps, be daunted by the fact that we find an infinite number of phenomena, far surpassing our imagination, and very many others which confound its weakness. But enough has been said on this subject. The other abstract notions are nothing but modes of imagining in which the imagination is differently affected, though they are considered by the ignorant as the chief attributes of things, inasmuch as they believe that everything was created for the sake of themselves; and, according as they are affected by it, style it good or bad, healthy or rotten and corrupt. For instance, if the motion which objects we see communicate to our nerves be conducive to health, the objects causing it are styled beautiful; if a contrary motion be excited, they are styled ugly.

Things which are perceived through our sense of smell are styled fragrant or fetid; if through our taste, sweet or bitter, full-flavoured or insipid; if through our touch, hard or soft, rough or smooth, &c.

Whatsoever affects our ears is said to give rise to noise, sound, or harmony. In this last case, there are men lunatic enough to believe, that even God himself takes pleasure in harmony; and philosophers are not lacking who have persuaded themselves, that the motion of the heavenly bodies gives rise to harmony—all of which instances sufficiently show that everyone judges of things according to the state of his brain, or rather mistakes for things the forms of his imagination. We need no longer wonder that there have arisen all the controversies we have witnessed, and finally scepticism: for, although human bodies in many respects agree, yet in very many other they differ; so that what seems good to one seems bad to another; what seems ordered to one seems confused to another; what is pleasing to one displeases another, and so on. I need not further enumerate, because this is not the place to treat the subject at length, and also because the fact is sufficiently well known. It is commonly said: "So many men, so many minds; everyone is wise in his own way; brains differ as completely as palates." All of which proverbs show, that men judge of things according to their mental disposition, and rather imagine than understand: for, if they understood phenomena, they would, as mathematics attest, be convinced, if not attracted, by what I have urged.

We have now perceived, that all the explanations commonly given of nature are mere modes of imagining, and do not indicate the true nature of anything, but only the constitution of the imagination; and, although they have names, as though they were entities, existing externally to the imagination, I call them entities imaginary rather than real; and, therefore, all arguments against us drawn from such abstractions are easily rebutted.

Many argue in this way. If all things follow from a necessity of the absolutely perfect nature of God, why are there so many imperfections in nature? such, for instance, as things corrupt to the point of putridity, loathsome deformity, confusion, evil, sin, &c. But these reasoners are, as I have said, easily confuted, for the perfection of things is to be reckoned only from their own nature and power; things are not more or less perfect, according as they delight or offend human senses, or according as they are serviceable or repugnant to mankind. To those who ask why God did not so create all men, that they should be governed only by reason, I give no answer but this: because matter was not lacking to him for the creation of every degree of perfection from highest to lowest; or, more strictly, because the laws of his nature are so vast, as to suffice for the production of everything conceivable by an infinite intelligence, as I have shown in Prop. xvi.

Such are the misconceptions I have undertaken to note; if there are any more of the same sort, everyone may easily dissipate them for himself with the aid of a little reflection.

LEIBNITZ

Gottfried Wilhelm Leibnitz was born June 21 [old style], 1646. His father was the actuary of the University of Leipzig. He was a very precocious child, for example, learning Latin at eight years of age without the use of a grammar by reading and rereading Livy. He entered the university of his home town at fifteen and paid particular attention to law. He was refused a doctor's degree in law at Leipzig on account of his age, but obtained it at Altorf, and was offered a professorship there, but refused it.

In 1668 he published his "New Method of Learning and Teaching Jurisprudence," which aroused considerable interest. He became active in politics and tried to find a ground for the reconcilation of Catholicism and Protestantism. Huyghens initiated him into higher mathematics, and soon afterwards, Leibnitz invented the Differential Calculus.

He was for some time councillor and a member of the supreme court of Brunswick-Lüneburg, and became a friend of a number of the princes of the continent.

In 1714 he wrote his "Monadology." This sought to get back of the Cartesian dualism of mind and matter by spiritualizing the conception of the atom and making each monad, so-called, an individuality. To the lowest order he assigned merely action as in the crystal; to a higher, life and unconscious thought as in the plant; to the next higher, conscious thought as in the animal; to the highest, self-consciousness. The supreme monad in such a scheme would be God. The harmony between them he thought to be pre-established by God. Many of his ideas are embodied in the present day conception of the cell, and such a conception of the universe is certainly as possible logically as is the conception of the physical world being built up of atoms.

He died November 14, 1716.

THE MONADOLOGY

1. The monad, of which we shall here speak, is merely a simple substance, that enters into compounds; simple, that is to say, without parts.

2. And there must be simple substances, since there are compound substances, for the compound is only a collection or aggregation of the simple.

3. Now where there are no parts, neither extension, nor figure, nor divisibility is possible. And these monads are the true atoms of nature, and, in a word, the elements of things.

4. Destruction also is not to be feared, and there is no conceivable way in which a simple substance can perish naturally.

5. For the same reason there is no way in which a simple substance can begin naturally, since it cannot be formed by composition.

6. Hence it may be said that the monads can begin or end only all at once, that is to say, they can begin only by creation and end by annihilation; whereas what is compound begins or ends by parts.

7. There is also no evident way how a monad can be altered or changed internally by any other creature, for nothing can be transposed within it, nor can there be conceived in it any internal movement that can be excited, directed, augmented or diminished within it, as can be done in compounds, where there is change among the parts. The monads have no windows through which anything can enter or depart. Accidents cannot detach themselves or go forth from the substances, as formerly the *sensible species* of the Schoolmen. And neither substance nor accident can enter a monad from without.

8. Nevertheless, the monads must have some qualities, otherwise they would not even be entities. And if simple substances did not differ at all in their qualities there would be no way whereby we could perceive any changes in things, since what is in the compound can only come from the simple ingredients, and if the monads were without qualities they could not be distinguished from one another, since also they do not differ in quantity. Consequently, a plenum being supposed, each place in any change of parts could receive only the same as what it had had before, and one state of things would not be distinguishable from another.

9. Moreover each monad must differ from every other. For in nature two beings are never exactly alike and such that it is not possible to find an internal difference or one founded upon an intrinsic analysis.

10. I take it for granted also that every created being, and consequently the created monad also, is subject to change, and also that this change is continual in each.

11. It follows from what has just been said, that the natural changes of the monads proceed from an internal principle, since an external cause cannot influence their interior.

12. But besides the principle of change, there must be particu-

man, and man that he might worship Him). I will, therefore, consider this opinion, asking first, why it obtains general credence, and why all men are naturally so prone to adopt it? secondly, I will point out its falsity; and, lastly, I will show how it has given rise to prejudices about good and bad, right and wrong, praise and blame, order and confusion, beauty and ugliness, and the like. However, this is not the place to deduce these misconceptions from the nature of the human mind: it will be sufficient here, if I assume as a starting point, what ought to be universally admitted, namely, that all men are born ignorant of the causes of things, that all have the desire to seek for what is useful to them, and that they are conscious of such desire. Herefrom it follows, first, that men think themselves free inasmuch as they are conscious of their volitions and desires, and never even dream, in their ignorance, of the causes which have disposed them so to wish and desire; secondly, that men do all things for an end, namely, for that which is useful to them, and which they seek. Thus it comes to pass that they only look for a knowledge of the final causes of events, and when these are learned, they are content, as having no cause for further doubt. If they cannot learn such causes from external sources, they are compelled to turn to considering themselves, and reflecting what end would have induced them personally to bring about the given event, and thus they necessarily judge other natures by their own. Further, as they find in themselves and outside themselves many means which assist them not a little in their search for what is useful, for instance, eyes for seeing, teeth for chewing, herbs and animals for yielding food, the sun for giving light, the sea for breeding fish, &c., they come to look on the whole of nature as a means for obtaining such conveniences. Now as they are aware, that they found these conveniences and did not make them, they think they have cause for believing, that some other being has made them for their use. As they look upon things as means, they cannot believe them to be self-created; but, judging from the means which they are accustomed to prepare for themselves, they are bound to believe in some ruler or rulers of the universe endowed with human freedom, who have arranged and adapted everything for human use. They are bound to estimate the nature of such rulers (having no information on the subject) in accordance with their own nature, and therefore they assert that the gods ordained everything for the use of man, in order to bind man to themselves and obtain from him the highest honour. Hence also it follows, that everyone thought out for himself, according to his abilities, a different way of worshipping God, so that God might love him more than his fellows, and direct the whole course of nature for the satisfaction of his blind cupidity and insatiable avarice. Thus the prejudice developed into superstition, and took deep root in the human mind; and for this reason everyone strove most zealously to understand and explain the final causes of things; but in their endeavour to show that nature does nothing in vain, i. e., nothing which is useless to man, they only seem to have demonstrated that nature, the gods, and men are all mad together. Consider, I pray you, the result: among the many helps of nature they were bound to find some hindrances, such as storms, earthquakes, diseases, &c.: so they declared that such things happen, because the gods are angry at some wrong done them by men, or at some fault committed in their worship. Experience day by day protested and showed by infinite examples, that good and evil fortunes fall to the lot of pious and impious alike; still they would not abandon their inveterate prejudice, for it was more easy for them to class such contradictions among other unknown things of whose use they were ignorant, and thus to retain their actual and innate condition of ignorance, than to destroy the whole fabric of their reasoning and start afresh. They therefore laid down as an axiom, that God's judgments far transcend human understanding. Such a doctrine might well have sufficed to conceal the truth from the human race for all eternity, if mathematics had not furnished another standard of verity in considering solely the essence and properties of figures without regard to their final causes. There are other reasons (which I need not mention here) besides mathematics, which might have caused men's minds to be directed to these general prejudices, and have led them to the knowledge of the truth.

I have now sufficiently explained my first point. There is no need to show at length, that nature has no particular goal in view, and that final causes are mere human figments. This, I think, is already evident enough, both from the causes and foundations on which I have shown such prejudice to be based, and also from Prop. xvi., and the Corollary of Prop. xxxii., and, in fact, all those propositions in which I have shown, that everything in nature proceeds from a sort of necessity, and with the utmost perfection. However, I will add a few remarks, in order to overthrow this doctrine of a final cause utterly. That which is really a cause it considers as an effect, and *vice versa:* it makes that which is by nature first to be last, and that which is highest and most perfect to be most imperfect. Passing over the questions of cause and priority as self-evident, it is plain from Props. xxi., xxii., xxiii. that that effect is most perfect which is produced immediately by God; the effect which requires for its production several intermediate causes is, in that respect, more imperfect. But if those things which were made immediately by God were made to enable him to attain his end, then the things which come after, for the sake of which the first were made, are necessarily the most excellent of all.

Further, this doctrine does away with the perfection of God: for, if God acts for an object, he necessarily desires something which he lacks. Certainly, theologians and metaphysicians draw a distinction between the object of want and the object of assimilation; still they confess that God made all things for the sake of himself, not for the sake of creation. They are unable to point to anything prior to creation, except God himself, as an object for which God should act, and are therefore driven to admit (as they clearly must), that God lacked those things for whose attainment he created means, and further that he desired them.

We must not omit to notice that the followers of this doctrine, anxious to display their talent in assigning final causes, have imported a new method of argument in proof of their theory—namely, a reduction, not to the impossible, but to ignorance; thus showing that they have no other method of exhibiting their doctrine. For example, if a stone falls from a roof on to someone's head, and kills him, they will demonstrate by their new method, that the stone fell in order to kill the man; for, if it had not by God's will fallen with that object, how could so many circumstances (and there are often many concurrent circumstances) have all happened together by chance? Perhaps you will answer that the event is due to the facts that the wind was blowing, and the man was walking that way. "But why," they will insist, "was the wind blowing, and why was the man at that very time walking that way?" If you again answer, that the wind had then sprung up because the sea had begun to be agitated the day before, the weather being previously calm, and that the man had been invited by a friend, they will again insist:

"But why was the sea agitated, and why was the man invited at that time?" So they will pursue their questions from cause to cause, till at last you take refuge in the will of God—in other words, the sanctuary of ignorance. So, again, when they survey the frame of the human body, they are amazed; and being ignorant of the causes of so great a work of art, conclude that it has been fashioned, not mechanically, but by divine and supernatural skill, and has been so put together that one part shall not hurt another.

Hence anyone who seeks for the true causes of miracles, and strives to understand natural phenomena as an intelligent being, and not to gaze at them like a fool, is set down and denounced as an impious heretic by those, whom the masses adore as the interpreters of nature and the gods. Such persons know that, with the removal of ignorance, the wonder which forms their only available means for proving and preserving their authority would vanish also. But I now quit this subject, and pass on to my third point.

After men persuaded themselves, that everything which is created is created for their sake, they were bound to consider as the chief quality in everything that which is most useful to themselves, and to account those things the best of all which have the most beneficial effect on mankind. Further, they were bound to form abstract notions for the explanation of the nature of things, such as goodness, badness, order, confusion, warmth, cold, beauty, deformity, and so on; and from the belief that they are free agents arose the further notions praise and blame, sin and merit.

I will speak of these latter hereafter, when I treat of human nature; the former I will briefly explain here.

Everything which conduces to health and the worship of God they have called good, everything which hinders these objects they have styled bad; and inasmuch as those who do not understand the nature of things do not verify phenomena in any way, but merely imagine them after a fashion, and mistake their imagination for understanding, such persons firmly believe that there is an order in things, being really ignorant both of things and their own nature. When phenomena are of such a kind, that the impression they make on our senses requires little effort of imagination, and can consequently be easily remembered, we say that they are well-ordered; if the contrary, that they are ill-ordered or confused. Further, as things which are easily imagined are more pleasing to us, men prelar changes in what changes, which forms, so to speak, the specification and variety of the simple substances.

13. This detail must involve multitude in unity or in the simple. For since every natural change is made by degrees, something changes and something remains; consequently, there must be in the simple substance a plurality of affections and of relations, although not of parts.

14. This transient state, which involves and represents multitude in unity or in the simple substance, is only what we call perception, which must be distinguished from apperception or from consciousness, as will appear in what follows. Here it is that the Cartesians especially failed, who made no account of the perceptions of which we are not conscious. It is this also which made them suppose that only spirits are monads and that there are no souls in brutes or of other entities. They, with the vulgar, have also confounded a protracted state of unconsciousness with death, strictly speaking, and have therefore admitted the old scholastic prejudice of entirely separate souls, and have even confirmed weaker minds in their belief of the mortality of the soul.

15. The action of the internal principle which causes the change of the passage from one perception to another, may be called appetition; it is true that this desire cannot always completely reach the whole perception toward which it tends, but it always attains to something of it and comes to new perceptions.

16. We experience in ourselves a case of multitude in a simple substance, when we find that the most trifling thought of which we are conscious involves variety in the object. Thus all who admit that the soul is a simple substance must also admit this multitude in the monad, and M. Bayle ought not to find in it the difficulties he mentions in his Dictionary, article *Rorarius*.

17. We must confess, moreover, that perception and what depends on it are inexplicable from mechanical causes, that is, by figures and motions. Supposing that there were a machine so constructed as to cause thought, feeling and perception, we could conceive of it enlarged and yet preserving the same proportions, so that we might enter it like a mill. And this granted, we should only find on visiting it, parts which push against one another, but never anything by which to explain a perception. It must be sought for, therefore, in the simple substance and not in the compound or ma-

chine. Nothing but this, also, can be found in the simple substance; and it is in this alone that all the internal actions of simple substances consist.

18. The name of *entelechies* (entities) might be given to all simple substances or created monads, for they have within themselves a certain perfection; there is a certain sufficiency which renders them the sources of their internal actions, and so to speak, incorporeal automata.

19. If we care to give the name soul to everything that has perceptions and desires in the general sense which I have just explained, all simple substances or created monads may be called souls, but as feeling is something more than a simple perception, I am willing that the general name of monads or entelechies shall suffice for those simple substances which have only perception, and that only those substances shall be called souls whose perception is more distinct and is accompanied by memory.

20. For we experience in ourselves a state in which we remember nothing and have no distinguishable perceptions, as, for instance, when we fall in a swoon or when we are overpowered by a profound and dreamless sleep. In this state the soul does not differ sensibly from a simple monad; but as this state is not continuous and as the soul frees itself from it, it is something more than a simple monad.

21. Yet it does not all follow that therefore the simple substance is without any perception. This is indeed impossible, for the reasons mentioned above; for it cannot perish, nor can it exist without some affection, which is nothing else than perception; but when there is a great number of minute perceptions, where nothing is distinct, we are stunned, as when we turn round and round in the same direction many times, whence arises a dizziness which may make us lose consciousness, and which does not allow us to see anything distinctly. So death may for a time produce this condition in animals.

22. And as the present state of every simple substance is the natural consequence of its preceding state, so its present is big with its future.

23. Therefore, since on being awakened from a stupor, we are aware of our perceptions, we must have had them immediately before although we were entirely unconscious of them; for one perception can

come naturally only from another perception as one motion can come naturally only from another motion.

24. From this we see that if there were nothing distinct, nothing, as may be said, in relief or of a higher flavor, in our perceptions, we should always be in a dazed state. This is a condition of the naked monad.

25. Thus we see that nature has given to animals higher perceptions, by the care she has taken to furnish them with organs which collect many rays of light or many undulations of air, in order to render them more powerful by their union. There is something of the same kind in odor, in taste, in touch and perhaps in a multitude of other senses which are unknown to us. I shall presently explain how what takes place in the soul represents what occurs in the organs.

26. Memory gives the souls a sort of consecutiveness which is like reason, but which ought to be distinguished from it. We observe that animals, seeing something which may strike them and of which they have had a similar perception before, expect, through their memory, what was associated with it in the preceding perception, and experience feelings similar to those which they had at that time. For instance, if we show dogs the cane, they remember the pain it has caused them and whine and run.

27. And the powerful imagination which strikes and moves them, arises either from the magnitude or the multitude of preceding perceptions. For often a strong impression produces all at once the same effect as a long continued habit, or as many repeated moderate perceptions.

28. Men are like the brutes in so far as the consecutiveness of their perceptions only results from the principle of memory, resembling the empirical physicians who practice without theory, and we are mere empirics in three-fourths of our actions. For example, when we expect that there will be daylight to-morrow, we are acting as empirics, because this has always taken place. It is only the astronomer who expects it from grounds of reason.

29. The knowledge of necessary and eternal truths is what distinguishes us from mere animals and gives us reason and the sciences, by raising us to a knowledge of ourselves and of God. This is what we call the reasonable soul or spirit within us.

30. It is also by this knowledge of necessary truths, and their abstractions, that we rise to acts of reflection, which make us think of that which calls itself " I," and consider that this or that is within us; and it

is thus that, in thinking of ourselves, we think of being, of substance, simple or compound, of the immaterial and of God Himself, conceiving that what with us is limited is with Him unlimited. These reflective acts constitute the principal objects of our reasonings.

31. Our reasonings are founded on two great principles, that of contradiction, by virtue of which we judge that to be false which involves self-contradiction and that true, which is opposed or contradictory to the false.

32. And that of the sufficient reason, by virtue of which we consider that no fact can be real or existent, no statement true, unless there is a sufficient reason why it is so and not otherwise, although for the most part these reasons cannot be known to us.

33. There are also two sorts of truths, those of reasoning and those of fact. Truths of reasoning are necessary and their opposite is impossible, and those of fact are contingent and their opposite is possible. When a truth is necessary its reason can be found by analysis, resolving it into more simple ideas and truths until we reach those that are elemental.

34. It is thus that mathematicians by analysis reduce speculative theorems and practical canons to definitions, axioms and postulates.

35. Finally there are simple ideas, definitions of which cannot be given; there are also axioms and postulates, in a word, elementary principles, which cannot be proved and indeed need no proof, and these are identical propositions, the opposite of which contains a self-contradiction.

36. But there must also be a sufficient reason for contingent truths, or those of fact,—that is, for the series of things throughout the universe of created objects—where the analysis into particular reasons might run into a detail without limits, on account of the immense variety of objects and the division of bodies *ad infinitum*. There is an infinity of figures and of movements, present and past, which enter into the efficient cause of my present writing, and there is an infinity of trifling motives and dispositions, past and present, of my soul, which enter into the final cause.

37. And as all such detail only depends on other contingents, anterior or more detailed, each one of which needs a like analysis for its explanation, we make no advance, and the sufficient or final reason must be outside of the sequence or series of this detail of contingencies, however infinite it may be.

38. And thus it is that the final cause of things must be found in a necessary substance, in which the detail of changes exists only transcendently, as in their source, and this is what we call God.

39. Now this substance being the sufficient reason of all this detail, which also is linked together throughout, there is but one God, and this God suffices.

40. We may judge also that this supreme essence, which is unique, universal and necessary, having nothing outside of itself which is independent of it, and being the simple series of possible being, must be incapable of limitations and must contain as much of reality as is possible.

41. Hence God is absolutely perfect, perfection being only the extension of positive reality taken in its strictest sense, setting aside the limits or bounds to what is limited. And there where there are no limits, that is, in God, perfection is absolutely infinite.

42. It follows also that creatures take their perfections from the influence of God, but that their imperfections arise from their own nature, which is incapable of existing without limits. For it is by this that they are distinguished from God.

43. It is also true that in God is the ground not only of existence but also of essences, so far as they are real, or of what is real in the possible. This is because the understanding of God is the source of eternal truths, or of the ideas on which they depend, and because, without him, nothing possible would be real and there would be not only nothing existing but also nothing possible.

44. Nevertheless, if there is any reality in essences or possibilities or in eternal truths, this reality must be founded in something existing and actual; consequently in the existence of the necessary being in whom essence involves existence or with whom to be possible is sufficient to be actual.

45. Hence God (or the necessary being) alone has the characteristic that he must exist if it is possible. And since nothing can hinder the possibility of that which has no limitations, no negation, and, consequently, no contradiction, this alone is enough to establish the existence of God *a priori*. We have also proved it by the reality of eternal truths. But we have just proved it also *a posteriori*, since contingent beings do exist which can have their final cause or sufficient reason only in a necessary being who has the reason of his existence in himself.

46. But it must not be thought, as is sometimes done, that eternal truths, being dependent upon God, are arbitrary and depend upon his

will, as Descartes seems to have conceived, and afterwards M. Poiret. This is true only of contingent truths, the principle of which is fitness or the choice of the best, whereas necessary truths depend solely on his understanding and are its internal nature.

47. Thus God alone is the elemental unity or the original simple substance; of which all monads, created or derived, are the products, and are born, so to speak, from moment to moment by continual emanation of the Divinity, limited by the capacity of the creature, to which limitation is essential.

48. In God is Power, which is the source of all things; then Knowledge, which contains the detail of ideas; and finally Will, which effects changes or products according to the principles of what is best. It is this which corresponds to what in created monads forms the subject or basis, the faculty of perception and desire. But in God these attributes are absolutely infinite or perfect, and in the created monads or in the *entelechies* (or *perfectihabies,* as Harmolaus Barbarus translated the word), they are only imitations proportioned to their perfection.

49. The creature is said to act in its environment in so far as it is perfect, and to suffer from another in so far as it is imperfect. Thus action is attributed to the monad in so far as it has clear perceptions, and passiveness in so far as it has confused perceptions.

50. And one creature is more perfect than another in that there is found in it what can account *a priori* for what takes place in another, and it is in this way that one is said to act upon another.

51. But in simple substances the influence of one monad upon another is purely ideal, since it can take effect only through the mediation of God, inasmuch as in the ideas of God a monad may demand with reason that God in regulating the others from the commencement of things, have regard to it. For since a created monad can have no physical influence upon the interior of another, it is only in this way that one can be dependent upon another.

52. And hence it is that the action and passiveness of creatures are mutual. For God, in comparing two simple substances, finds in each one reasons which compel him to adjust the other to it, and consequently that which in certain respects is active, is from another point of view, passive; active in so far as what is known distinctly in it, serves to account for what takes place in another; and passive in so far as the cause of what takes place in it, is found in what is clearly known in another.

53. Now, as there is an infinity of possible universes in the mind of God, and as only one of them can exist, there must be a sufficient reason for the choice of God, by which He decides for one rather than for another.

54. And this reason can only be found in the fitness, in the degree of perfection, which these worlds contain, each possible world having the right to claim existence according to the measure of perfection which it would possess.

55. And this is the cause of the existence of the Best, which wisdom makes known to God, which His goodness chooses and which His power produces.

56. Now this connection, or this adaptation of all created things to each and of each to all, brings it about that each simple substance in its relations expresses all the others, and that consequently it is a living, perpetual mirror of the universe.

57. And as the same city viewed from different sides appears entirely different and in appearance is as if multiplied, so also it happens that, because of the infinite multiplicity of simple substances, there are as it were so many different universes, which are nevertheless only the appearances of a single one, from the different points of view of each monad.

58. And this is the way to obtain as great a variety as possible, but with the greatest possible order; that is, it is the way to obtain as much perfection as possible.

59. Thus this hypothesis (which I dare to assert is proved) is the only one which brings out the grandeur of God. M. Bayle recognized this, when in his Dictionary (Art. *Rorarius*) he objected to it; where indeed he was tempted to believe that I accorded to God more than was possible. But he can state no reason why this universal harmony which brings it about that each substance expresses exactly all others in the relations it sustains to them, is impossible.

60. Besides, we can see in what I have just said *a priori* reasons why things could not be otherwise, because God, in regulating all, has regard to each part, and especially to each monad, since, its nature being representative, nothing can limit it to representing only a part of things; although it may be true that this representation is confused as regards the detail of the whole universe, and distinct only in the case of a few things, that is to say, in the case only of those which are nearest or largest in relation to each of the monads—otherwise each monad would be

a divinity. It is not in the object but only in the modification of the knowledge of the object, that monads are limited. They all tend confusedly toward the infinite, toward the whole, but they are limited, and are to be distinguished by their degrees of clear perception.

61. And in this respect compound substances are like simple substances. For since the world is a *plenum,* making all matter interrelated, and since in a plenum every movement has some effect on distant bodies in proportion to their distance, so that each body is affected not only by those that touch it and feels in some way all that happens to them, but also by their means is affected by those which touch the first with which it is in immediate contact, it follows that this communication extends to every distance whatever. Therefore each body feels all that passes in the universe, so that he who sees all, could read in each that which passes everywhere else, and even that which has been or shall be, perceiving in the present that which is distant in time as well as in space; *sumpnoia panta,* said Hippocrates. But a soul can read in itself only what is expressly represented in it. It cannot develop its laws all at once, for they reach into the infinite.

62. Thus, although each created monad represents all the universe, it represents most distinctly the body which is particularly appropriated to it and of which it forms the entelechy; and as this body represents the entire universe by the interconnection of all matter in a plenum, the soul also represents the whole universe by representing that body which especially belongs to it.

63. The body belonging to a monad, which is the entelechy or soul, constitutes, with the entelechy, what may be called a living being, and with the soul, what may be called an animal. Now this body of a living being or of an animal is always organic, for as every monad is in a way a mirror of the universe, and as the universe is in perfect order, there must also be an order in the representative, that is, in the perceptions of the soul, and hence in the body, in like manner as the universe is represented in it.

64. Hence every organic body of a living being is a sort of divine machine or natural automaton, which infinitely surpasses all artificial automata, because a machine which is made by human art is not a machine in every one of its parts; for example, the tooth of a brass wheel has parts or fragments which to us are no longer artificial and have nothing in themselves to show the use to which the wheel was destined in the machine. But nature's machines, that is, living bodies, are ma-

chines even to their most infinitesimal parts. In this lies the difference between nature and art, that is, between the divine art and ours.

65. And the author of nature has been able to contrive these divine and infinitely marvellous works of art, because each particle of matter is not only divisible *ad infinitum*, as the ancients perceived, but also each part is actually infinitely subdivided into parts of which each has its own motion; otherwise it would be impossible for each portion of matter to represent the universe.

66. Hence we see that there is a world of creatures, of living beings, of animals, of entelechies, of souls, in the smallest particle of matter.

67. Each particle of matter may be thought of as a garden full of plants, or as a pond full of fishes. But each branch of the plant, each member of the animal, each drop of its humors is also such a garden or such a pond.

68. And although the earth or air between the plants of the garden, or the water between the fish of the pond, is neither plant nor fish, it yet contains more of them, but for the most part so tiny as to be to us imperceptible.

69. Hence there is nothing uncultivated, sterile or dead in the universe, no chaos or confusion save in appearance, such as a pond would present from a distance in which we might see the confused movement and swarming, so to speak, of the fishes in the pond, without perceiving the fish themselves.

70. Thus we see that every living body has a ruling entelechy that is the soul of the animal, but the particles of this living body are full of other living beings—plants, animals—each of which has also its entelechy or governing soul.

71. But it must not be thought, as has been done by some people who have misunderstood my idea, that every soul has a mass or portion of matter allotted to it or united to it forever, and that hence it possesses other inferior living beings doomed to its service forever. For all bodies are, like rivers, in a perpetual flux, and parts are always joining and leaving them.

72. Hence the soul changes its body only gradually and by degrees, so that it is never deprived of all its organs at once. There is often a metamorphosis in animals, but never a metempsychosis or transmigration of souls. There are also no absolutely separate souls, nor genii without bodies. Only God is wholly without body.

73. For which reason also, it follows that there is, strictly speaking, neither absolute generation nor absolute death, where the soul is separated from the body. What we call generation is development or increase, as also what we call death is involution and diminution.

74. Philosophers have been greatly puzzled over the origin of forms, entelechies, or souls; but now, when we know by close investigation of plants, insects and animals, that organic bodies in nature are never generated hit and miss or from putrefaction, but always from seeds, in which there was undoubtedly some pre-formation, it has been thought that not only the organic body was already there before conception, but also a soul in this body, and, in a word, the animal itself; and that by means of conception this animal has merely been destined to a greater transformation, in order to become an animal of another kind. Something like this is seen outside of generation, as when worms become flies, and caterpillars, butterflies.

75. Of such animals, those that are raised by conception to the grade of larger animals, may be called *spermatics;* but those which remain in their class, that is, the most part, are born, multiply, and die like the larger animals, and there is only a small number of chosen ones, which pass to a larger theater.

76. But this tells only half the truth; I have therefore thought that if the animal never naturally has a beginning, it cannot end naturally; and that not only will there be no generation, but also no absolute destruction or death strictly speaking. And these reasonings, made *a posteriori* and drawn from experience, harmonizes perfectly with principles deduced *a priori*, as above.

77. Thus it may be said that not only is the soul (the mirror of an indestructible universe) indestructible, but also the animal itself, although its machine often perishes in part and takes on or puts off organic spoils.

78. These principles have given me the means of explaining naturally the union or rather the conformity of the soul and the organic body. The soul follows its own peculiar laws and the body also follows its own laws, and they meet by virtue of the pre-established harmony between all substances, since they all represent one and the same universe.

79. Souls act according to the laws of final causes, by desires, ends and means. Bodies act in accordance with the laws of efficient causes or of motion. And the two realms, that of efficient causes and that of final causes, are in harmony with each other.

80. Descartes saw that souls cannot add any motion to bodies, because there is always the same quantity of force in matter; nevertheless he believed that the soul could change the direction of the motion. But it was because, in his day, the law of nature which declares the conservation of the total direction in matter, was not known. If he had known this, he would have lighted upon my system of the pre-established harmony.

81. Under this system bodies can act as if (what is impossible) there were no souls, and souls act as if there were no bodies, and both act as if each influenced the other.

82. Although I find that the same thing I have stated—namely, that animals and souls begin only with the world and end only with the world—holds good in the end with regard to all animals and living things, yet there is this peculiarity in rational animals, that their spermatic animalcules, as such, have only ordinary or sensitive souls, but as soon as those which are, so to speak, elected, attain by actual conception to human nature, their sensitive souls are elevated to the rank of reason and to the prerogative of spirits.

83. Among other differences that exist between ordinary souls and spirits, a part of which I have already mentioned, there is also this, that souls in general are the living mirrors or images of the universe of creatures, but spirits are in addition images of the Divinity itself, or of the author of nature, able to know the system of the universe and to imitate something of it constructively, since every spirit is like a little divinity in its own department.

84. For this reason the spirits can enter into a sort of society with God, and He is, in relation to them, not only what an inventor is to his machines (as God is in relation to the other creatures), but also what a prince is to his subjects or even a father to his children.

85. Whence it is easy to conclude that the community of all spirits must compose the City of God, that is, the most perfect state which is possible, under the most perfect of monarchs.

86. This City of God, this truly universal dominion, is a moral world within the natural world, and the highest and most divine of the works of God; it is in this that the glory of God truly consists, for He would have none if His greatness and goodness were not known and admired by spirits. It is, too, only in relation to the divine city that He possesses, properly, goodness; while His wisdom and power are everywhere manifest.

87. As we have thus established perfect harmony between two natural kingdoms, the one of efficient, the other of final causes, we should also notice here another harmony between the physical kingdom of nature and the moral kingdom of grace; that is, between God considered as an architect of the mechanism of the universe, and God, considered as monarch of the divine city of souls.

88. This harmony makes all things evolve toward grace by natural methods. This globe, for example, must be destroyed and repaired by natural means, at such times as the government of spirits may demand it, for the punishment of some and the reward of others.

89. It may be said, besides, that God the architect satisfies in every respect God the legislator, and that therefore sins, by the laws of nature and even the mechanical structure of things, must carry their punishment with them; and that good actions will obtain their rewards by mechanical ways through their relation to bodies, although this may not and ought not always take place at once.

90. Finally, under this perfect government, there will be no good action without its reward, no bad action without its atonement, and everything must result for the well-being of the good, that is, of those who are not out of harmony with this great State, who, after having done their duty, trust in providence, and who love and imitate as they ought the author of all good, pleasing themselves with the contemplation of His perfections,—according to the nature of truly pure love, which is happy in the happiness of the loved one. This is why the wise and virtuous work at all things which seem in harmony with the divine will, presumptive or antecedent, and yet content themselves with what God actually sends by His secret, consequent and decisive will, recognizing that if we could sufficiently comprehend the order of the universe we would find that it surpassed all the wishes of the wisest, and that it is impossible to make it better than it is, not only for all in general, but even for ourselves in particular, if we are attached, as we should be, to the Author of all, not only as the architect and efficient cause of our being, but also as our master and final cause, who should be the only aim of our efforts, and who can alone secure our happiness.

HOBBES

THOMAS HOBBES was born at Westport (now part of Malmesbury) April 5, 1588. His father, vicar of the place, got into trouble by quarrelling with a rival, and left his children to the care of his brother, a glover of Malmesbury. He early studied Greek and Latin and at fifteen entered Oxford, where he was graduated in 1608, although he seems to have taken little interest in the scholastic learning of the time.

For some years afterwards he was tutor, then secretary and friend to young Cavendish. Cavendish died in 1628, but in 1631 Hobbes became the tutor of the son.

In 1637 he became interested in the idea that everything, mind included, can be explained by being referred to motion in nature. Then came the Puritan revolution, and Hobbes took the side of the Stuart kings,—in fact, in 1647 he was made instructor in mathematics of the exiled Prince of Wales. His *Leviathan* was published in 1651. In it he tried to apply mechanical principles to society as he had previously tried to assign them to nature. Society he thought to be an organism, its basis a contract by which the people had alienated their rights to the king in return for protection. He considered the best government to be a monarchy, but raised the question of the right of the subject to change allegiance when the power of the king to protect is gone. This brought him enemies on both sides, and he took the least dangerous course and returned to England. His doctrines of a mechanical nature and society offended the clergy, but after the Restoration he was received with some honor by the king, and the only punishment he received was the condemnation of his works by parliament as atheistic (1666). He died in 1679.

The question of what was the supreme power in the state was handed down along with the idea of the Social Contract to Locke and Rousseau.

The Leviathan besides containing the idea that society is an organism, and the theory of the Social Contract, given in the following volume, psychologically traces all sensation to motion in the body and its environment. The carrying out of this theory of sense to its logical limit would make mental facts as entirely subject to natural laws as physical. Hence Hobbes' influence, which still persists, is on the side of materialism. Something of his idea that motion is the cause of all sensation follows.

OF MAN

CHAPTER I.

OF SENSE

CONCERNING the thoughts of man, I will consider them first singly, and afterwards in train, or dependence upon one another. Singly, they are every one a *representation* or *appearance*, of some quality, or other accident of a body without us, which is commonly called an *object*. Which object worketh on the eyes, ears, and other parts of a man's body; and by diversity of working, produceth diversity of appearances.

The original of them all, is that which we call SENSE, for there is no conception in a man's mind, which hath not at first, totally, or by parts, been begotten upon the organs of sense. The rest are derived from that original.

To know the natural cause of sense, is not very necessary to the business now in hand; and I have elsewhere written of the same at large. Nevertheless, to fill each part of my present method, I will briefly deliver the same in this place.

The cause of sense, is the external body, or object which presseth the organ proper to each sense, either immediately, as in the taste and touch; or mediately, as in seeing, hearing, and smelling; which pressure, by the mediation of the nerves, and other strings and membranes of the body, continued inwards to the brain and heart, causeth there a resistance, or counter-pressure, or endeavour of the heart to deliver itself, which endeavour, because *outward*, seemeth to be some matter without. And this *seeming*, or *fancy*, is that which men call *sense;* and consisteth, as to the eye, in a *light*, or *colour figured;* to the ear, in a *sound;* to the nostril, in an *odour;* to the tongue and palate, in a *savour;* and to the rest of the body, in *heat, cold, hardness, softness,* and such other qualities as we discern by *feeling*. All which qualities, called *sensible*, are, in the object that causeth them, but so many several motions of the matter, by which it presseth our organs diversely. Neither in us that are pressed, are they any thing else but divers motions; for motion produceth nothing but motion. But their appearance to us is fancy, the same waking, that dreaming. And as pressing, rubbing, or striking the eye, makes us fancy a light; and pressing the ear, produceth a din; so do the bodies also we see, or hear, produce the same by their strong, though unobserved action. For if those colours and sounds were in the bodies, or objects that cause them, they could not be severed from them, as by glasses, and in echoes by reflection, we see they are; where we know the thing we see is in one place, the appearance in another. And though at some certain distance, the real and very object seem invested with the fancy it begets in us; yet still the object is one thing, the image or fancy is another. So that sense, in all cases, is nothing else but original fancy, caused, as I have said, by the pressure, that is, by the motion, of external things upon our eyes, ears, and other organs thereunto ordained.

But the philosophy-schools, through all the universities of Christendom, grounded upon certain texts of Aristotle, teach another doctrine, and say, for the cause of *vision,* that the thing seen sendeth forth on every side a *visible species,* in English, a *visible show, apparition,* or *aspect,* or *a being seen;* the receiving whereof into the eye, is *seeing.* And for the cause of *hearing,* that the thing heard sendeth forth an *audible species,* that is, an *audible aspect,* or *audible being seen;* which *audible species,* that is an *audible aspect,* or *audible being seen;* which entering at the ear, maketh *hearing.* Nay, for the cause of *understanding* also, they say the thing understood, sendeth forth an *intelligible species,* that is, an *intelligible being seen;* which, coming into the understanding, makes us understand. I say not this, as disproving the use of universities; but because I am to speak hereafter of their office in a commonwealth, I must let you see on all occasions by the way, what things would be amended in them; amongst which the frequency of insignificant speech is one.

CHAPTER II.

OF IMAGINATION

THAT when a thing lies still, unless somewhat else stir it, it will lie still for ever, is a truth that no man doubts of. But that when a thing is in motion, it will eternally be in motion, unless somewhat else stay it, though the reason be the same, namely, that nothing can change itself, is not so easily assented to. For men measure, not only other men, but all other things, by themselves; and because they find themselves subject after motion to pain, and lassitude, think every thing else grows weary of motion, and seeks repose of its own accord; little considering, whether it be not some other motion, wherein that desire of rest they find in themselves, consisteth. From hence it is, that the schools say, heavy bodies fall downwards, out of an appetite to rest, and to conserve their nature in that place which is most proper for them; ascribing appetite, and knowledge of what is good for their conservation, which is more than man has, to things inanimate, absurdly.

When a body is once in motion, it moveth, unless something else hinder it, eternally; and whatsoever hindreth it, cannot in an instant, but in time, and by degrees, quite extinguish it; and as we see in the water, though the wind cease, the waves give not over rolling for a long time after: so also it happeneth in that motion, which is made in the internal parts of a man, then, when he sees, dreams, &c. For after the object is removed, or the eye shut, we still retain an image of the thing seen, though more obscure than when we see it. And this is it, the Latins call *imagination,* from the image made in seeing; and apply the same, though improperly, to all the other senses. But the Greeks call it *fancy;* which signifies *appearance,* and is as proper to one sense, as to another. IMAGINATION therefore is nothing but *decaying sense;* and is found in men, and many other living creatures, as well sleeping, as waking.

The decay of sense in men waking, is not the decay of the motion made in sense; but an obscuring of it, in such manner as the light of the sun obscureth the light of the stars; which stars do no less exercise their virtue, by which they are visible, in the day than in the night. But because amongst many strokes, which our eyes, ears, and other organs receive from external bodies, the predominant only is sensible; therefore, the light of the sun being predominant, we are not affected with the action of the stars. And any object being removed from our eyes, though the impression it made in us remain, yet other objects more present succeeding, and working on us, the imagination of the past is obscured, and made weak, as the voice of a man is in the noise of the day. From whence it followeth, that the longer the time is, after the sight or sense of any object, the weaker is the imagination. For the continual change of man's body destroys in time the parts which in sense were moved: so that distance of time, and of place, hath one and the same effect in us. For as at a great distance of place, that which we look at appears dim, and without distinction of the smaller parts; and as voices grow weak, and inarticulate; so also, after great distance of time, our imagination of the past is weak; and we lose, for example, of cities we have seen, many particular streets, and of actions, many particular circumstances. This *decaying sense,* when we would express the thing itself, I mean *fancy* itself, we call *imagination,* as I said before: but when we would express the decay, and signify that the sense is fading, old, and past, it is called *memory.* So that imagination and memory are but one thing, which for divers considerations hath divers names.

Much memory, or memory of many things, is called *experience.* Again, imagination being only of those things which have been formerly perceived by sense, either all at once, or by parts at several times; the former, which is the imagining the whole object as it was presented to the sense, is *simple* imagination, as when one imagineth a man, or horse, which he hath seen before. The other is *compounded;* as when, from the sight of a man at one time, and of a horse at another, we conceive in our mind a Centaur. So when a man compoundeth the image of his own person with the image of the actions of another man, as when a man imagines himself a Hercules or an Alexander, which happeneth often to them that are much taken with reading of romances, it is a compound imagination, and properly but a fiction of the mind. There be also other imaginations that rise in men, though waking, from the great impression made in sense: as from gazing upon the sun, the impression leaves an image of the sun before our eyes a long time after; and from being long and vehemently attent upon geometrical figures, a man shall in the dark, though awake, have the images of lines and angles before his eyes; which kind of fancy hath no particular name, as being a thing that doth not commonly fall into men's discourse.

The imaginations of them that sleep are those we call *dreams.* And these also, as all other imaginations, have been before, either totally or by parcels, in the sense. And because in sense, the brain and nerves, which are the necessary organs of sense, are so benumbed in sleep, as not easily to be moved by the action of external objects, there can happen in sleep no imagination, and therefore no dream, but what proceeds from the agitation of the inward parts of man's body; which inward parts, for the connexion they have with the brain, and other organs, when they be distempered, do keep the same in motion; whereby the imaginations there formerly made, appear as if a man were waking;

saving that the organs of sense being now benumbed, so as there is no new object, which can master and obscure them with a more vigorous impression, a dream must needs be more clear, in this silence of sense, than our waking thoughts. And hence it cometh to pass, that it is a hard matter, and by many thought impossible, to distinguish exactly between sense and dreaming. For my part, when I consider that in dreams I do not often nor constantly think of the same persons, places, objects, and actions, that I do waking; nor remember so long a train of coherent thoughts, dreaming, as at other times; and because waking I often observe the absurdity of dreams, but never dream of the absurdities of my waking thoughts; I am well satisfied, that being awake, I know I dream not, though when I dream I think myself awake.

CHAPTER VI.

OF THE INTERIOR BEGINNINGS OF VOLUNTARY MOTIONS; COMMONLY CALLED THE PASSIONS; AND THE SPEECHES BY WHICH THEY ARE EXPRESSED

THERE be in animals, two sorts of *motions* peculiar to them: one called *vital;* begun in generation, and continued without interruption through their whole life; such as are the *course* of the *blood*, the *pulse*, the *breathing*, the *concoction*, *nutrition*, *excretion*, &c., to which motions there needs no help of imagination: the other is *animal motion*, otherwise called *voluntary motion;* as to *go*, to *speak*, to *move* any of our limbs, in such manner as is first fancied in our minds. (That sense is motion in the organs and interior parts of man's body, caused by the action of the things we see, hear, &c.; and that fancy is but the relics of the same motion, remaining after sense, has been already said in the first and second chapters.) And because *going*, *speaking*, and the like voluntary motions, depend always upon a precedent thought of *whither*, *which way*, and *what;* it is evident, that the imagination is the first internal beginning of all voluntary motion. And although unstudied men do not conceive any motion at all to be there, where the thing moved is invisible; or the space it is moved in is, for the shortness of it, insensible; yet that doth not hinder, but that such motions are. For let a space be never so little, that which is moved over a greater space, whereof that little one is part, must first be moved over that. These small beginnings of motion, within the body of man, before they appear in walking, speaking, striking, and other visible actions, are commonly called ENDEAVOUR.

This endeavour, when it is toward something which causes it, is called APPETITE, or DESIRE; the latter, being the general name; and the other oftentimes restrained to signify the desire of food, namely *hunger* and *thirst*. And when the endeavour is fromward something, it is generally called AVERSION. These words, *appetite* and *aversion*, we have from the Latins; and they both of them signify the motions one of approaching, the other of retiring. So also do the Greek words for the same, which are *horma* and *aphorma*. For nature itself does often press upon men those truths, which afterwards, when they look for somewhat beyond nature, they stumble at. For the Schools find in mere appetite to go, or move, no actual motion at all: but because some motion they must acknowledge, they call it metaphorical motion; which is but an absurd speech: for though words may be called metaphorical; bodies and motions can not.

That which men desire, they are also said to LOVE: and to HATE those things for which they have aversion. So that desire and love are the same thing; save that by desire, we always signify the absence of the object; by love, most commonly the presence of the same. So also by aversion, we signify the absence; and by hate, the presence of the object.

Of appetites and aversions, some are born with men; as appetite of food, appetite of excretion, and exoneration, which may also and more properly be called aversions, from somewhat they feel in their bodies; and some other appetites, not many. The rest, which are appetites of particular things, proceed from experience, and trial of their effects upon themselves or other men. For of things we know not at all, or believe not to be, we can have no further desire, than to taste and try. But aversion we have for things, not only which we know have hurt us, but also that we do not know whether they will hurt us, or not.

Those things which we neither desire, nor hate, we are said to *contemn*; CONTEMPT being nothing else but an immobility, or contumacy of the heart, in resisting the action of certain things; and proceeding from that the heart is already moved otherwise, by other more potent objects; or from want of experience of them.

And because the constitution of a man's body is in continual mutation, it is impossible that all the same things should always cause in him the same appetites, and aversions; much less can all men consent, in the desire of almost any one and the same object.

But whatsoever is the object of any man's appetite or desire, that is it which he for his part calleth *good*: and the object of his hate and aversion, *evil;* and of his contempt, *vile* and *inconsiderable.* For these words of good, evil, and contemptible, are ever used with relation to the person that useth them: there being nothing simply and absolutely so; nor any common rule of good and evil, to be taken from the nature of the objects themselves; but from the person of the man, where there is no commonwealth; or, in a commonwealth, from the person that representeth it; or from an arbitrator or judge, whom men disagreeing shall by consent set up, and make his sentence the rule thereof.

The Latin tongue has two words, whose significations approach to those of good and evil; but are not precisely the same; and those are *pulchrum* and *turpe.* Whereof the former signifies that which by some apparent signs promiseth good; and the latter, that which promiseth evil. But in our tongue we have not so general names to express them by. But for *pulchrum* we say in some things, *fair;* in others, *beautiful,* or *handsome,* or *gallant,* or *honourable,* or *comely,* or *amiable;* and for *turpe, foul, deformed, ugly, base, nauseous,* and the like, as the subject shall require; all which words, in their proper places, signify nothing else but the *mien,* or countenance, that promiseth good and evil. So that of good there be three kinds; good in the promise, that is *pulchrum;* good in effect, as the end desired, which is called *jucundum, delightful;* and good as the means, which is called *utile, profitable;* and as many of evil: for *evil* in promise, is that they call *turpe;* evil in effect, and end, is *molestum, unpleasant, troublesome;* and evil in the means, *inutile, unprofitable, hurtful.*

As, in sense, that which is really within us, is, as I have said before, only motion, caused by the action of external objects, but in apparence; to the sight, light and colour; to the ear, sound; to the nostril, odour, &c.: so, when the action of the same object is continued from the eyes, ears, and other organs to the heart, the real effect there is nothing but motion, or endeavour; which consisteth in appetite, or aversion, to or from the object moving. But the apparence, or sense of that motion, is that we either call *delight,* or *trouble of mind.*

This motion, which is called appetite, and for the apparence of it *delight,* and *pleasure,* seemeth to be a corroboration of vital motion, and a help thereunto; and therefore such things as caused delight, were not improperly called *jucunda, a juvando,* from helping or fortifying; and the contrary, *molesta, offensive,* from hindering, and troubling the motion vital.

Pleasure therefore, or *delight,* is the apparence, or sense of good;

and *molestation*, or *displeasure*, the apparence, or sense of evil. And consequently all appetite, desire, and love, is accompanied with some delight more or less; and all hatred and aversion, with more or less displeasure and offence.

Of pleasures or delights, some arise from the sense of an object present; and those may be called *pleasure of sense;* the word *sensual*, as it is used by those only that condemn them, having no place till there be laws. Of this kind are all onerations and exonerations of the body; as also all that is pleasant, in the *sight, hearing, smell, taste*, or *touch*. Others arise from the expectation, that proceeds from foresight of the end, or consequence of things; whether those things in the sense please or displease. And these are *pleasures of the mind* of him that draweth those consequences, and are generally called JOY. In the like manner, displeasures are some in the sense, and called PAIN; others in the expectation of consequences, and are called GRIEF.

These simple passions called *appetite, desire, love, aversion, hate, joy*, and *grief*, have their names for divers considerations diversified. As first, when they one succeed another, they are diversely called from the opinion men have of the likelihood of attaining what they desire. Secondly, from the object loved or hated. Thirdly, from the consideration of many of them together. Fourthly, from the alteration or succession itself.

LOCKE

JOHN LOCKE was born at Wrington, Somersetshire, England, in 1632. His first education was at Westminster School, London. From 1651 to 1664 he was at Oxford. Three years later he became a member of the family of Lord Ashley, afterwards Earl of Shaftesbury, and was led into politics. He received several offices and became something of a leader of political thought. His Civil Government was too liberal to suit King James, and Locke was forced to live on the continent for five years. In 1690 he published his Essay on the Human Understanding. The book marks the beginning of descriptive psychology, for, while its avowed purpose is "to inquire into the original, certainty, and extent of human knowledge," yet it is actually a descriptive analysis of knowledge more than an examination of the ground of all knowledge. Besides this analysis, however, there are two features of Locke's system that have had great influence. The first is that he declares all knowledge to come from experience, i. e., from sensation and subsequent reflection. The second is that he points out that our sensations are not the things themselves, nor necessarily copies of the things, but that they represent powers or qualities, and that we presuppose the things as a support for a number of such qualities, the sensations from which are continually recurring together in our mind. Hence Locke is the spirit of sensualistic materialism on the one side, and on the other from his doctrine that substance is merely something presupposed as the ground of sensations grew Berkeley's idealism.

He died October 28, 1704.

IDEAS

OF IDEAS IN GENERAL AND THEIR ORIGINAL

1. *Idea is the Object of Thinking.*—Every man being conscious to himself that he thinks, and that which his mind is applied about whilst thinking, being the ideas that are there, it is past doubt that men have in their minds several ideas, such as are those expressed by the words whiteness, hardness, sweetness, thinking, motion, man, elephant, army, drunkenness, and others. It is in the first place then to be inquired how he comes by them. I know it is a received doctrine that men have native ideas and original characters stamped upon their minds in their very first being. This opinon I have at large examined already; and I suppose what I have said in the foregoing book will be much more easily admitted when I have shown whence the understanding may get all the ideas it has, and by what ways and degrees they may come into the mind; for which I shall appeal to every one's own observation and experience.

2. *All Ideas Come from Sensation or Reflection.*—Let us then suppose the mind to be, as we say, white paper, void of all characters, without any ideas; how comes it to be furnished? Whence comes it by that vast store which the busy and boundless fancy of man has painted on it with an almost endless variety? Whence has it all the materials of reason and knowledge? To this I answer in one word, from experience;

in that all our knowledge is founded, and from that it ultimately derives itself. Our observation employed either about external sensible objects, or about the internal operations of our minds, perceived and reflected on by ourselves, is that which supplies our understandings with all the materials of thinking. These two are the fountains of knowledge from whence all the ideas we have or can naturally have do spring.

3. *The Objects of Sensation one Source of Ideas.*—First, our senses, conversant about particular sensible objects, do convey into the mind several distinct perceptions of things, according to those various ways wherein those objects do affect them; and thus we come by those ideas we have of yellow, white, heat, cold, soft, hard, bitter, sweet, and all those which we call sensible qualities; which when I say the senses convey into the mind, I mean, they from external objects convey into the mind what produces there those perceptions. This great source of most of the ideas we have, depending wholly upon our senses, and derived by them to the understanding, I call SENSATION.

4. *The Operations of Our Minds, the other Source of them.*—Secondly, the other fountain, from which experience furnisheth the understanding with ideas, is the perception of the operations of our own mind within us, as it is employed about the ideas it has got; which operations, when the soul comes to reflect on and consider, do furnish the understanding with another set of ideas, which could not be had from things without; and such are perception, thinking, doubting, believing, reasoning, knowing, willing, and all the different actings of our own minds; which we being conscious of, and observing in ourselves, do from these receive into our understandings as distinct ideas, as we do from bodies affecting our senses. This source of ideas every man has wholly in himself; and though it be not sense, as having nothing to do with external objects, yet it is very like it, and might properly enough be called internal sense. But as I call the other Sensation, so I call this REFLECTION, the ideas it affords being such only as the mind gets by reflecting on its own operations within itself. By reflection then, in the following part of this discourse, I would be understood to mean that notice which the mind takes of its own operations, and the manner of them; by reason whereof there come to be ideas of these operations in the understanding. These two, I say, viz., external material things, as the objects of sensation; and the operations of our own minds within, as the objects of reflection; are to me the only originals from whence all our ideas take their beginnings. The term operations here I use in

a large sense, as comprehending not barely the actions of the mind about its ideas, but some sort of passions arising sometimes from them, such as is the satisfaction or uneasiness arising from any thought.

5. *All our Ideas are of the one or the other of these.*—The understanding seems to me not to have the least glimmering of any ideas which it doth not receive from one of these two. External objects furnish the mind with the ideas of sensible qualities, which are all those different perceptions they produce in us; and the mind furnishes the understanding with ideas of its own operations.

These, when we have taken a full survey of them, and their several modes, combinations, and relations, we shall find to contain all our whole stock of ideas; and that we have nothing in our minds, which did not come in one of these two ways. Let any one examine his own thoughts, and thoroughly search into his understanding; and then let him tell me, whether all the original ideas he has there, are any other than of the objects of his senses, or of the operations of his mind, considered as objects of his reflection: and how great a mass of knowledge soever he imagines to be lodged there, he will, upon taking a strict view, see that he has not any idea in his mind, but what one of these two have imprinted, though, perhaps, with infinite variety compounded and enlarged by the understanding, as we shall see hereafter.

6. *Observable in Children.*—He that attentively considers the state of a child, at his first coming into the world, will have little reason to think him stored with plenty of ideas, that are to be the matter of his future knowledge: it is by degrees he comes to be furnished with them. And though the ideas of obvious and familiar qualities imprint themselves before the memory begins to keep a register of time or order, yet it is often so late before some unusual qualities come in the way, that there are few men that cannot recollect the beginning of their acquaintance with them; and if it were worth while, no doubt a child might be so ordered as to have but a very few, even of the ordinary ideas, till he were grown up to a man. But all that are born into the world being surrounded with bodies that perpetually and diversely affect them, variety of ideas, whether care be taken of it or not, are imprinted on the minds of children. Light and colours are busy at hand everywhere, when the eye is but open; sounds of some tangible qualities fail not to solicit their proper senses, and force an entrance to the mind; but yet, I think, it will be granted easily, that if a child were kept in a place where he never saw any other but black and white till he were a man,

he would have no more ideas of scarlet or green, than he that from his childhood never tasted an oyster or a pine-apple has of those particular relishes.

7. *Men are differently furnished with these, according to the different Objects they converse with.*—Men then come to be furnished with fewer or more simple ideas from without, according as the objects they converse with afford greater or less variety; and from the operations of their minds within, according as they more or less reflect on them. For though he that contemplates the operations of his mind, cannot but have plain and clear ideas of them; yet, unless he turns his thoughts that way, and considers them attentively, he will no more have clear and distinct ideas of all the operations of his mind, and all that may be observed therein, than he will have all the particular ideas of any landscape, or of the parts and motions of a clock, who will not turn his eyes to it, and with attention heed all the parts of it. The picture or clock may be so placed, that they may come in his way every day; but yet he will have but a confused idea of all the parts they are made up of, till he applies himself with attention to consider them each in particular.

8. *Ideas of Reflection later, because they need Attention.*—And hence we see the reason why it is pretty late before most children get ideas of the operations of their own minds; and some have not any very clear or perfect ideas of the greatest part of them all their lives; because, though they pass there continually, yet, like floating visions, they make not deep impressions enough to leave in their mind clear, distinct, lasting ideas, till the understanding turns inward upon itself, reflects on its own operations, and makes them the objects of its own contemplation. Children when they come first into it, are surrounded with a world of new things, which, by a constant solicitation of their senses, draw the mind constantly to them, forward to take notice of new, and apt to be delighted with the variety of changing objects. Thus the first years are usually employed and diverted in looking abroad. Men's business in them is to acquaint themselves with what is to be found without; and so growing up in a constant attention to outward sensation, seldom make any considerable reflection on what passes within them till they come to be of riper years, and some scarce ever at all.

9. *The Soul begins to have Ideas when it begins to perceive.*—To ask at what time a man has first any ideas, is to ask when he begins to perceive; having ideas, and perception, being the same thing. I know

it is an opinion, that the soul always thinks, and that it has the actual perception of ideas in itself constantly, as long as it exists, and that actual thinking is as inseparable from the soul as actual extension is from the body; which, if true, to inquire after the beginning of a man's ideas, is the same as to inquire after the beginning of his soul; for by this account, soul and its ideas, as body and its extension, will begin to exist both at the same time.

IDEAS AND THINGS

7. *Ideas in the Mind, Qualities in Bodies.*—To discover the nature of our ideas the better, and to discourse of them intelligently, it will be convenient to distinguish them as they are ideas or perceptions in our minds, and as they are modifications of matter in the bodies that cause such perceptions in us, that so we may not think (as perhaps usually is done) that they are exactly the images and resemblances of something inherent in the subject; most of those of sensation being in the mind no more the likeness of something existing without us, than the names that stand for them are the likeness of our ideas, which yet upon hearing they are apt to excite in us.

8. Whatsoever the mind perceives in itself, or is the immediate object of perception, thought, or understanding, that I call idea; and the power to produce any idea in our mind, I call quality of the subject wherein that power is. Thus a snowball having the power to produce in us the ideas of white, cold, and round, the power to produce these ideas in us, as they are in the snowball, I call qualities; and as they are sensations or perceptions in our understandings, I call them ideas; which ideas, if I speak of sometimes as in the things themselves, I would be understood to mean those qualities in the objects which produce them in us.

9. *Primary Qualities.*—Qualities thus considered in bodies are, first, such as are utterly inseparable from the body, in what state soever it be; such as in all the alterations and changes it suffers, all the force can be used upon it, it constantly keeps; and such as sense constantly finds in every particle of matter which has bulk enough to be perceived and the mind finds inseparable from every particle of matter, though less than to make itself singly be perceived by our senses, v. g., take a grain of wheat, divide it into two parts, each part has still solidity, extension, figure, and mobility; divide it again, and it retains still the

same qualities; and so divide it on till the parts become insensible, they must retain still each of them all those qualities. For division (which is all that a mill, or pestle, or any other body, does upon another, in reducing it to insensible parts) can never take away either solidity, extension, figure, or mobility from any body, but only makes two or more distinct separate masses of matter, of that which was but one before; all which distinct masses, reckoned as so many distinct bodies, after division, makes a certain number. These I call original or primary qualities of body, which I think we may observe to produce simple ideas in us, viz., solidity, extension, figure, motion or rest, and number.

10. *Secondary Qualities.*—Secondly, such qualities which in truth are nothing in the objects themselves, but powers to produce various sensations in us by their primary qualities, i. e., by the bulk, figure, texture, and motion of their insensible parts, as colours, sounds, tastes, etc., these I call secondary qualities. To these might be added a third sort, which are allowed to be barely powers, though they are as much real qualities in the subject, as those which I, to comply with the common way of speaking, call qualities, but for distinction, secondary qualities. For the power in fire to produce a new colour or consistency in wax or clay, by its primary qualities, is as much a quality in fire as the power it has to produce in me a new idea or sensation of warmth or burning, which I felt not before, by the same primary qualities, viz., the bulk, texture, and motion of its insensible parts.

11. *How primary Qualities produce their Ideas.*—The next thing to be considered is, how bodies produce ideas in us; and that is manifestly by impulse, the only way which we can conceive bodies to operate in.

12. If then external objects be not united to our minds when they produce ideas therein, and yet we perceive these original qualities in such of them as singly fall under our senses, it is evident that some motion must be thence continued by our nerves or animal spirits, by some parts of our bodies to the brain, or the seat of sensation, there to produce in our minds the particular ideas we have of them. And since the extension, figure, number, and motion of bodies of an observable bigness, may be perceived at a distance by the sight, it is evident some singly imperceptible bodies must come from them to the eyes, and thereby convey to the brain some motion, which produces these ideas which we have of them in us.

13. *How secondary.*—After the same manner that the ideas of

these original qualities are produced in us, we may conceive that the ideas of secondary qualities are also produced, viz., by the operations of insensible particles on our senses. For it being manifest that there are bodies and good store of bodies, each whereof are so small, that we cannot by any of our senses discover either their bulk, figure, or motion, as is evident in the particles of the air and water, and others extremely smaller than those, perhaps as much smaller than the particles of air and water, as the particles of air and water are smaller than peas or hail-stones; let us suppose at present, that the different motions and figures, bulk and number, of such particles, affecting the several organs of our senses, produce in us those different sensations which we have from the colours and smells of bodies; v. g., that a violet, by the impulse of insensible particles of matter of peculiar figure and bulks, and in different degrees and modifications of their motions, causes the idea of the blue colour and sweet scent of that flower to be produced in our minds; it being no more impossible to conceive that God should annex such ideas to such motions, with which they have no similitude, than that he should annex the idea of pain to the motion of a piece of steel dividing our flesh, with which that idea hath no resemblance.

14. What I have said concerning colours and smells may be understood also of taste and sounds, and other the like sensible qualities; which, whatever reality we by mistake attribute to them, are in truth nothing in the objects themselves, but powers to produce various sensations in us, and depend on those primary qualities, viz., bulk, figure, texture, and motion of parts, as I have said.

15. *Ideas of primary Qualities are Resemblances; of secondary, not.*—From whence I think it easy to draw this observation, that the ideas of primary qualities of bodies are resemblances of them, and their patterns do really exist in the bodies themselves; but the ideas produced in us by these secondary qualities have no resemblance of them at all. There is nothing like our ideas existing in the bodies themselves. They are in the bodies we denominate from them, only a power to produce those sensations in us; and what is sweet, blue, or warm in idea, is but the certain bulk, figure, and motion of the insensible parts in the bodies themselves, which we call so.

16. Flame is denominated hot and light; snow, white and cold; and manna, white and sweet, from the ideas they produce in us; which qualities are commonly thought to be the same in those bodies that those ideas are in us, the one the perfect resemblance of the other, as

they are in a mirror; and it would by most men be judged very extravagant, if one should say otherwise. And yet he that will consider that the same fire that at one distance produces in us the sensation of warmth, does at a nearer approach produce in us the far different sensation of pain, ought to bethink himself what reason he has to say that this idea of warmth, which was produced in him by the fire, is actually in the fire; and his idea of pain, which the same fire produced in him the same way, is not in the fire. Why are whiteness and coldness in snow, and pain not, when it produces the one and the other idea in us; and can do neither but by the bulk, figure, number, and motion of its solid parts?

17. The particular bulk, number, figure, and motion of the parts of fire or snow are really in them, whether any one's senses perceive them or not, and therefore they may be called real qualities, because they really exist in those bodies; but light, heat, whiteness, or coldness, are no more really in them than sickness or pain is in manna. Take away the sensation of them; let not the eye see light or colours, nor the ears hear sounds; let the palate not taste, nor the nose smell; and all colours, tastes, odours, and sounds, as they are such particular ideas, vanish and cease, and are reduced to their causes, i. e., bulk, figure, and motion of parts.

18. A piece of manna of a sensible bulk is able to produce in us the idea of a round or square figure; and by being removed from one place to another, the idea of motion. This idea of motion represents it as it really is in the manna moving; a circle or square are the same, whether in idea or existence, in the mind or in the manna; and this both motion and figure are really in the manna, whether we take notice of them or no; this everybody is ready to agree to. Besides, manna by the bulk, figure, texture, and motion of its parts, has a power to produce the sensations of sickness, and sometimes of acute pains or gripings in us. That these ideas of sickness and pain are not in the manna, but effects of its operations on us, and are nowhere when we feel them not, this also every one readily agrees to. And yet men are hardly to be brought to think that sweetness and whiteness are not really in manna, which are but the effects of the operations of manna, by the motion, size, and figure of its particles on the eyes and palate; as the pain and sickness caused by manna are confessedly nothing but the effects of its operations on the stomach and guts by the size, motion, and figure of its insensible parts, (for by nothing else can a body operate, as has been proved); as if it could not operate on the eyes and palate, and thereby produce in

the mind particular distinct ideas, which in itself it has not, as well as we allow it can operate on the guts and stomach, and thereby produce distinct ideas, which in itself it has not. These ideas being all effects of the operations of manna on several parts of our bodies, by the size, figure, number, and motion of its parts; why those produced by the eyes and palate should rather be thought to be really in the manna, than those produced by the stomach and guts; or why the pain and sickness ideas that are the effect of manna, should be thought to be nowhere when they are not felt; and yet the sweetness and whiteness, effects of the same manna on other parts of the body, by ways equally as unknown, should be thought to exist in the manna, when they are not seen or tasted, would need some reason to explain.

19. *Ideas of primary Qualities are Resemblances; of secondary, not.*—Let us consider the red and white colours in porphyry: hinder light from striking on it, and its colours vanish, it no longer produces any such ideas in us; upon the return of light it produces these appearances on us again. Can any one think any real alterations are made in the porphyry by the presence or absence of light, and that those ideas of whiteness or redness are really in porphyry in the light, when it is plain it has no colour in the dark? It has, indeed, such a configuration of particles, both night and day, as are apt, by the rays of light rebounding from some parts of that hard stone, to produce in us the idea of redness, and from others the idea of whiteness; but whiteness or redness are not in it at any time, but such a texture that hath the power to produce such a sensation in us.

20. Pound an almond, and the clear white colour will be altered into a dirty one, and the sweet taste into an oily one. What real alteration can the beating of the pestle make in any body, but an alteration of the texture of it?

21. Ideas being thus distinguished and understood, we may be able to give an account how the same water, at the same time, may produce the idea of cold by one hand and of heat by the other; whereas it is impossible that the same water, if those ideas were really in it, should at the same time be both hot and cold; for if we imagine warmth, as it is in our hands, to be nothing but a certain sort and degree of motion in the minute particles of our nerves or animal spirits, we may understand how it is possible that the same water may, at the same time, produce the sensations of heat in one hand and cold in the other; which yet figure never does, that never producing the idea of a square by one

hand which has produced the idea of a globe by another. But if the sensation of heat and cold be nothing but the increase or diminution of the motion of the minute parts of our bodies, caused by the corpuscles of any other body, it is easy to be understood, that if that motion be greater in one hand than in the other, if a body be applied to the two hands, which has in its minute particles a greater motion than in those of one of the hands, and a less than in those of the other, it will increase the motion of the one hand and lessen it in the other, and so cause the different sensations of heat and cold that depend thereon.

22. I have in what just goes before been engaged in physical inquiries a little further than perhaps I intended; but it being necessary to make the nature of sensation a little understood, and to make the difference between the qualities in bodies, and the ideas produced by them in the mind, to be distinctly conceived, without which it were impossible to discourse intelligently of them, I hope I shall be pardoned this little excursion into natural philosophy, it being necessary in our present inquiry to distinguish the primary and real qualities of bodies which are always in them, (viz., solidity, extension, figure, number, and motion, or rest, and are sometimes perceived by us, viz., when the bodies they are in are big enough singly to be discerned,) from those secondary and imputed qualities which are but the powers of several combinations of those primary ones, when they operate without being distinctly discerned; whereby we may also come to know what ideas are, and what are not, resemblances of something really existing in the bodies we denominate from them.

23. *Three Sorts of Qualities in Bodies.*—The qualities, then, that are in bodies, rightly considered, are of three sorts.

First, the bulk, figure, number, situation, and motion or rest of their solid parts; those are in them, whether we perceive them or not; and when they are of that size that we can discover them, we have by these an idea of the thing as it is in itself, as is plain in artificial things. These I call the primary qualities.

Secondly, the power that is in any body, by reason of its insensible primary qualities, to operate after a peculiar manner on any of our senses, and thereby produce in us the different ideas of several colours, sounds, smells, tastes, etc. These are usually called sensible qualities.

Thirdly, the power that is in any body, by reason of the particular constitution of its primary qualities, to make such a change in the bulk, figure, texture, and motion of another body, as to make it operate on our senses differently from what it did before. Thus the sun has a power to make wax white, and fire to make lead fluid. These are usually called powers.

The first of these, as has been said, I think may be properly called real, original, or primary qualities, because they are in the things themselves, whether they are perceived or not; and upon their different modifications it is that the secondary qualities depend.

The other two are only powers to act differently upon other things, which powers result from the different modifications of those primary qualities.

24. *The first are Resemblances; the second thought Resemblances, but are not; the third neither are, nor are thought so.*—But though the two latter sorts of qualities are powers barely, and nothing but powers, relating to several other bodies, and resulting from the different modifications of the original qualities, yet they are generally otherwise thought of; for the second sort, viz., the powers to produce several ideas in us by our senses, are looked upon as real qualities in the things thus affecting us; but the third sort are called and esteemed barely powers; e. g., the idea of heat or light, which we receive by our eyes or touch from the sun, are commonly thought real qualities existing in the sun, and something more than mere powers in it. But when we consider the sun in reference to wax, which it melts or blanches, we look on the whiteness and softness produced in the wax, not as qualities in the sun, but effects produced by powers in it; whereas, if rightly considered, these qualities of light and warmth, which are perceptions in me when I am warmed or enlightened by the sun, are no otherwise in the sun, than the changes made in the wax, when it is blanched or melted, are in the sun. They are all of them equally powers in the sun, depending on its primary qualities; whereby it is able, in the one case, so to alter the bulk, figure, texture, or motion of some of the insensible parts of my eyes or hands, as thereby to produce in me the idea of light or heat; and in the other, it is able to so alter the bulk, figure, texture, or motion of the insensible parts of the wax, as to make them fit to produce in me the distinct ideas of white and fluid.

25. The reason why the one are ordinarily taken for real qualities, and the other only for bare powers, seems to be, because the ideas we have of distinct colours, sounds, etc., containing nothing at all in them of bulk, figure, or motion, we are not apt to think them the effects of these primary qualities, which appear not, to our senses, to operate

in their production, and with which they have not any apparent congruity or conceivable connexion. Hence it is that we are so forward to imagine that those ideas are the resemblances of something really existing in the objects themselves; since sensation discovers nothing of bulk, figure, or motion of parts in their production; nor can reason show how bodies, by their bulk, figure, and motion, should produce in the mind the ideas of blue or yellow, etc. But in the other case, in the operations of bodies, changing the qualities one of another, we plainly discover that the quality produced hath commonly no resemblance with anything in the thing producing it; wherefore we look on it as a bare effect of power. For though receiving the idea of heat or light from the sun, we are apt to think it is a perception and resemblance of such a quality in the sun; yet when we see wax, or a fair face, receive changes of colour from the sun, we cannot imagine that to be the reception or resemblance of anything in the sun, because we find not those different colours in the sun itself. For our senses being able to observe a likeness or unlikeness of sensible qualities in two different external objects, we forwardly enough conclude the production of any sensible quality in any subject to be an effect of bare power, and not the communication of any quality, which was really in the efficient, when we find no such sensible quality in the thing that produced it; but our senses not being able to discover any unlikeness between the idea produced in us, and the quality of the object producing it, we are apt to imagine that our ideas are resemblances of something in the objects, and not the effects of certain powers placed in the modification of their primary qualities, with which primary qualities the ideas produced in us have no resemblance.

26. *Secondary Qualities twofold; first, immediately perceivable; secondly, mediately perceivable.*—To conclude, beside those before-mentioned primary qualities in bodies, viz., bulk, figure, texture, number, and motion of their solid parts, all the rest whereby we take notice of bodies, and distinguish them one from another, are nothing else but several powers in them depending on those primary qualities, whereby they are fitted, either by immediately operating on our bodies, to produce several different ideas in us, or else, by operating on other bodies, so to change their primary qualities as to render them capable of producing ideas in us different from what they did before. The former of these, I think, may be called secondary qualities, immediately perceivable; the latter, secondary qualities, mediately perceivable.

SUBSTANCE

OF OUR COMPLEX IDEAS OF SUBSTANCES

1. *Ideas of Substances, how made.*—The mind being, as I have declared, furnished with a great number of the simple ideas conveyed in by the senses, as they are found in exterior things, or by reflection on its own operations, takes notice also that a certain number of these simple ideas go constantly together; which being presumed to belong to one thing, and words being suited to common apprehensions and made use of for quick dispatch, are called, so united in one subject, by one name; which, by inadvertency, we are apt afterward to talk of and consider as one simple idea, which indeed is a complication of many ideas together; because, as I have said, not imagining how these simple ideas can subsist by themselves, we accustom ourselves to suppose some substratum wherein they do subsist, and from which they do result; which therefore we call substance.

2. *Our Idea of Substance in general.*—So that if any one will examine himself concerning his notion of pure substance in general, he will find he has no other idea of it at all, but only a supposition of he knows not what support of such qualities which are capable of producing simple ideas in us; which qualities are commonly called accidents. If any one should be asked, what is the subject wherein colour or weight inheres, he would have nothing to say, but the solid extended parts; and if he were demanded what is it that solidity and extension adhere in, he would not be in a much better case than the Indian before mentioned, who, saying that the world was supported by a great elephant, was asked what the elephant rested on; to which his answer was—a great tortoise. But being again pressed to know what gave support to the broad-backed tortoise, replied—something, he knew not what. And thus here, as in all other cases where we use words without having clear and distinct ideas, we talk like children; who being questioned what such a thing is, which they know not, readily give this satisfactory answer, that it is something: which in truth signifies no more, when so used either by children or men, but that they know not what; and that the thing they pretend to know and talk of, is what they have no distinct idea of at all, and so are perfectly ignorant of it, and in the dark. The idea then we have, to which we give the general name substance, being nothing

but the supposed but unknown support of those qualities we find existing, which we imagine cannot subsist, "sine re substante," without something to support them, we call that support *substantia;* which, according to the true import of the word, is in plain English, standing under or upholding.

3. *Of the Sorts of Substances.*—An obscure and relative idea of substance in general being thus made, we come to have the ideas of particular sorts of substances, by collecting such combinations of simple ideas as are, by experience and observation of men's senses, taken notice of to exist together, and are therefore supposed to flow from the particular internal constitution, or unknown essence of that substance. Thus we come to have the ideas of a man, horse, gold, water, etc., of which substances, whether any one has any other clear idea, further than of simple ideas coexistent together, I appeal to every one's own experience. It is the ordinary qualities observable in iron, or a diamond, put together, that make the true complex idea of those substances, which a smith or jeweller commonly knows better than a philosopher; who, whatever substantial form he may talk of, has no other idea of those substances, than what is framed by a collection of those simple ideas which are to be found in them; only we must take notice, that our complex ideas of substances, besides all those simple ideas they are made up of, have always the confused idea of something to which they belong and in which they subsist. And therefore when we speak of any sort of substance, we say it is a thing having such or such qualities; as body is a thing that is extended, figured, and capable of motion; spirit, a thing capable of thinking; and so hardness, friability, and power to draw iron, we say, are qualities to be found in a loadstone. These, and the like fashions of speaking, intimate that the substance is supposed always something besides the extension, figure, solidity, motion, thinking, or other observable ideas, though we know not what it is.

4. *No clear idea of Substance in general.*—Hence, when we talk or think of any particular sort of corporeal substances, as horse, stone, etc., though the idea we have of either of them be but the complication or collection of those several simple ideas of sensible qualities, which we used to find united in the thing called horse or stone; yet, because we cannot conceive how they should subsist alone, nor one in another, we suppose them existing in and supported by some common subject; which support we denote by the name substance, though it be certain we have no clear or distinct idea of that thing we suppose a support.

5. *As clear an Idea of Spirit as Body.*—The same thing happens concerning the operations of the mind, viz., thinking, reasoning, fearing, etc., which we concluding not to subsist of themselves, nor apprehending how they can belong to body, or be produced by it, we are apt to think these the actions of some other substance, which we call spirit; whereby yet it is evident that, having no other idea or notion of matter, but something wherein those many sensible qualities which affect our senses do subsist; by supposing a substance wherein thinking, knowing, doubting, and a power of moving, etc., do subsist, we have as clear a notion of its substance of spirit, as we have of body: the one being supposed to be (without knowing what it is) the substratum to those simple ideas we have from without; and the other supposed (with a like ignorance of what it is) to be the substratum to those operations we experiment in ourselves within. It is plain then, that the idea of corporeal substance in matter is as remote from our conceptions and apprehensions, as that of spiritual substance or spirit; and therefore, from our not having any notion of the substance of spirit, we can no more conclude its non-existence, than we can, for the same reason, deny the existence of body; it being as rational to affirm there is no body, because we have no clear and distinct idea of the substance of matter, as to say there is no spirit, because we have no clear and distinct idea of the substance of a spirit.

SEVENTEENTH CENTURY NATURAL SCIENCE

FROM THE CHRISTIANIZATION of Europe in the early Middle Ages to the end of the Thirty Years' War in 1648, the most important subjects for thought were religious. The great minds of Europe mostly spent their efforts on this field. With the discovery of America in 1492 came the first great break in the old order of things. The beginning of modern natural science was made by Copernicus, Galileo, Kepler, and Bacon, and from the middle of the seventeenth century, the growth of the natural sciences has been so rapid that they now constitute by far the greater part of that legacy from generation to generation which we call the world's knowledge.

Before looking at the work itself of the scientists of the seventeenth century, it will give us a better bird's-eye view of the development of the subject to run over the chief advances of the period.

The ideas of Galileo, Kepler and Bacon, whose work made memorable the first of the seventeenth century, have already been noted in a previous volume.

Harvey in 1619 founded physiology by demonstrating the circulation of the blood. Soon afterwards (in 1622) Asellius discovered the lacteal circulation, and in 1649 Olaüs Rüdbeck of Sweden found that these lacteals or lymphatics furnished the thoracic duct, and thus the heart, with the material for new blood. In 1690 Van Leeuwenhoeck strengthened Harvey's theory by discovering the capillary circulation of the blood from the arteries to the veins.

In physics, the advances were many and great. Torricelli invented the barometer (1644) and Pascal (1656) by showing that the mercury rises to different heights at different altitudes above the earth, proved that it is the weight of the air which causes the rise of the mercury. Guericke in 1650 invented the air pump and in 1672 the first electrical machine. Newton proved the compound nature of light in 1666-71. Roemer in 1676 estimated its velocity by noting the difference in the apparent time of the eclipses of Jupiter's moons, depending upon whether the earth is upon the side of its orbit nearest or farthest from Jupiter. The greatest variation observed was 16 minutes and 36 seconds, or 996 seconds, and the diameter of the earth's orbit was thought to be about 190,000,000 miles. Light would then travel about 190,000 miles in a second. Huyghens took up the question of the nature of light and in 1678 developed his wave theory and his conception of ether as the medium through which light moves. In 1682 Newton worked out his law of gravitation and showed that weight is the result of an attractive force between masses of matter, that acts throughout all the immensity of the solar system.

A first foundation was laid in biology. Malphigi making use of the microscope discovered the capillaries between the ends of the arteries and the veins, the air-cells in the lungs, the color cells beneath the outer layer of the skin, and along with Grew in 1670 began modern botany by pointing out the cell-system in plants and that flowers differ in sex analogously with animals. In 1677 Leeuwenhoeck discovered the animalculae in water, thus opening up a vast world of microscopic life hitherto undreamed of, in 1690 the actual capillary circulation, and made many important investigations on insect-anatomy.

In chemistry, which began to break away from alchemy, Boyle discovered that gases are compressed practically in proportion to the pressure upon them (about 1665). Mayow in 1674 demonstrated that there is some component in the air necessary for breathing and combustion, but his discovery had to be remade a hundred years later.

Thus the seventeenth century saw the work of the world's greatest astronomers, the foundation of physiology, the great law of gravitation, the first interpretation of sensation—light and sound—in terms of motion, the first law in chemistry, and the first insight into the world revealed by the microscope.

ANTHONY VON LEEUWENHOECK

Anthony Von Leeuwenhoeck was born at Delft, Holland, 1632. His trade was that of lens-maker for microscopes, and his scientific spirit led him from this into researches with the instruments he made.

He made several great discoveries and many others of less importance. In 1673 he noticed the red globules in the blood. In 1675 he discovered the animalculæ in water, thus making a first beginning in bacteriology. He first described the spermatazoa in 1677. In 1690 he traced the passage of the blood from the arteries into the veins by the capillaries, thus filling in the gap in Harvey's theory. He also noted the tubules of teeth, the solidity of hair, the structure of the epidermis. His descriptions of the anatomy of insects are classical. In theoretical biology he stood for the idea that everything generated its kind, and against spontaneous generation. Outside of his scientific studies his life was uneventful. Most of his discoveries were announced to the Royal Society of London. He died in 1723.

OBSERVATIONS ON ANIMALCULA SEEN IN RAIN, WELL, SEA AND SNOW-WATER; AS ALSO IN PEPPER-WATER

In the year 1675, I discovered very small living creatures in rain water, which had stood but few days in a new earthen pot glazed blue within. This invited me to view this water with great attention, especially those little animals appearing to me ten thousand times less than those represented by M. Swammerdam, and by him called water-fleas, or water-lice, which may be perceived in the water with the naked eye.

The first sort I several times observed to consist of 5, 6, 7, or 8 clear globules without being able to discern any film that held them together, or contained them. When these animalcula or living atoms moved, they put forth two little horns, continually moving. The space between these two horns was flat, though the rest of the body was roundish, sharpening a little towards the end, where they had a tail, near four times the length of the whole body, of the thickness, by my microscope, of a spider's web; at the end of which appeared a globule of the size of one of those which made up the body. These little creatures, if they chanced to light on the least filament or string, or other particle, were entangled therein, extending their body in a long round, and endeavoring to disentangle their tail. Their motion of extension and contraction continued a while; and I have seen several thousands of these poor little creatures, within the space of a grain of gross sand, lie fast clustered together in a few filaments.

I also discovered a second sort, of an oval figure; and I imagined their head to stand on a sharp end. These were a little longer than the former. The inferior part of their body is flat, furnished with several extremely thin feet, which moved very nimbly. The upper part of the body was round, and had within 8, 10, or 12 globules, where they were very clear. These little animals sometimes changed their figure into a perfect round, especially when they came to lie on a dry place. Their body was also very flexible; for as soon as they struck against any the smallest fibre or string, their body was bent in, which bending presently jerked out again. When I put any of them on a dry place, I observed that, changing themselves into a round, their body was raised pyramidalwise, with an extant point in the middle; and having laid thus a little while, with a motion of their feet, they burst asunder, and the globules were presently diffused and dissipated, so that I could not discern the least thing of any film, in which the globules had doubtless been enclosed; and at this time of their bursting asunder, I was able to discover more globules than when they were alive.

I observed a third sort of little animals, that were twice as long as broad, and to my eye eight times smaller than the first. Yet I thought I discerned little feet, whereby they moved very briskly, both in round and straight line.

There was a fourth sort, which were so small that I was not able to give them any figure at all. These were a thousand times smaller than the eye of a large louse. These exceeded all the former in celerity. I have often observed them to stand still as it were on a point, and then turn themselves about with that swiftness, as we see a top turn round, the circumference they made being no larger than that of a grain of small sand, and then extending themselves straight forward, and by and by lying in a bending posture. I discovered also several other sorts of animals; these were generally made up of such soft parts, as the former, that they burst asunder as soon as they came to want water.

May 26, it rained hard; the rain growing less, I caused some of that rain-water running down from the house top, to be gathered in a clean glass, after it had been washed two or three times with water. And in this I observed some few very small living creatures, and seeing them, I thought they might have been produced in the leaded gutters in some water that had remained there before.

I perceived in pure water, after some days, more of those animals, as also some that were somewhat larger. And I imagine, that many thousands of these little creatures do not equal an ordinary grain of sand in bulk; and comparing them with a cheese-mite, which may be seen to move with the naked eye, I make the proportion of one of these small water-creatures to a cheese-mite to be like that of a bee to a horse; for, the circumference of one of these little animals in water is not so large as the thickness of a hair in a cheese-mite.

In another quantity of rain-water, exposed for some days to the air, I observed some thousands of them in a drop of water, which were of the smallest sort that I had seen hitherto. And in some time after I observed, besides the animals already noted, a sort of creatures that were eight times as large, of almost a round figure; and as those very small animalcula swam gently among each other, moving as gnats do in the air, so did these larger ones move far more swiftly, tumbling round as it were, and then making a sudden downfall.

In the waters of the river Maese I saw very small creatures of different kinds and colours, and so small, that I could very hardly discern their figures; but the number of them was far less than those found in rain-water. In the water of a very cold well in the autumn, I discovered a very great number of living animals very small, that were exceedingly clear, and a little larger than the smallest I ever saw. In sea water I observed at first, a little blackish animal, looking as if it had been made up of two globules. This creature had a peculiar motion, resembling the skipping of a flea on white paper, so that it might very well be called a water-flea; but it was far less than the eye of that little animal, which Dr. Swammerdam calls the water-flea. I also discovered little creatures therein that were clear, of the same size with the former animal, but of an oval figure, having a serpentine motion. I further noticed a third sort, which were very slow in their motion; their body was of a mouse colour, clear towards the oval point; and before the head and behind the body there stood out a sharp little point angle-wise. This sort was a little larger. But there was yet a fourth somewhat longer than oval. Yet of all these sorts there were but a few of each. Some days after viewing this water, I saw 100 where before I had seen but one; but these were of another figure, and not only less, but they were also very clear, and of an oblong oval figure, only with this difference, that their heads ended sharper; and although they were a thousand times smaller than a small grain of sand, yet when they lay out of the water in a dry place, they burst in pieces and spread into three or four very little globules, and into some aqueous matter, without any other parts appearing in them.

Having put about one-third of an ounce of whole pepper in water, and it having lain about three weeks in the water, to which I had twice added some snow-water, the other water being in great part exhaled; I discerned in it with great surprise an incredible number of little animals, of divers kinds, and among the rest, some that were three or four times as long as broad; but their whole thickness did not much exceed the hair of a louse. They had a very pretty motion, often tumbling about and sideways; and when the water was let to run off from them, they turned round like a top; at first their body changed into an oval, and afterwards, when the circular motion ceased, they returned to their former length. The second sort of creatures discovered in this water, were of a perfect oval figure, and they had no less pleasing or nimble a motion than the former; and these were in far greater numbers. There was a third sort, which exceeded the two former in number, and these had tails like those I had formerly observed in rain-water. The fourth sort, which moved through the three former sorts, were incredibly small, so that I judged, that if 100 of them lay one by another, they would not equal the length of a grain of coarse sand; and according to this estimate, 1,000,000 of them could not equal the dimensions of a grain of such coarse sand. There was discovered a fifth sort, which had near the thickness of the former, but almost twice the length.

In snow-water, which had been about three years in a glass bottle well stopped, I could discover no living creatures; and having poured some of it into a porcelain tea-cup, and put therein half an ounce of whole pepper, after some days I observed some animalcula, and those exceedingly small ones, whose body seemed to me twice as long as broad, but they moved very slowly, and often circularly. I observed also a vast multitude of oval-figured animalcula, to the number of 6,000 or 8,000 in a single drop.—Transactions of the Royal Society.

NEWTON

Sir Isaac Newton was born at Woolstrop, Lincolnshire, England, Dec. 25, 1642 (O. S.). His father, a farmer of good descent, had died before he was born. He attended the free grammar school at Grantham, but left early. His ability in making mechanical toys, however, brought his mother to return him to school, and later send him to Cambridge. He took his degree in 1665, in 1667 was made a fellow of the university, and in 1669 professor of mathematics. He had already discovered his method of fluxions, which closely resembles Leibnitz's Differential Calculus, invented about the same time.

In 1672 he was elected a member of the Royal Society and soon afterwards sent to them his communication concerning how he had broken up light by means of a prism, thus showing the compound nature of the sun's rays.

In 1682 a new measurement of the meridian was brought to his notice. Sixteen years before he had conceived the idea of universal gravity and had calculated the pull the earth would exert on the moon in accordance with its supposed mass. The result had not agreed with the speed of revolution of the moon and Newton had laid the hypothesis aside. He saw that the new calculation of the size of the earth was in the right direction and set to work at a re-calculation of the problem. The solution is given below.

When he saw that the hypothesis of a universal attraction between masses was coming close to agreeing with the known facts, he was so agitated that he had to ask a friend to complete it for him.

Some years later he began to investigate chemistry, but the story is that his papers were destroyed by his dog and he never quite recovered from the shock. From 1695 to 1699 he was warden of the mint, and from 1699 to his death master of the mint, a place paying from $6,000 to $9,000 a year.

He died March 20, 1727. His discoveries in light, in gravitation, including the universal theory and its application to the planets and the tides, or in mathematics would any one of them make his name deserving of immortality.

THE DIFFUSION OF LIGHT

A letter of Mr. Isaac Newton, Professor of Mathematics in the University of Cambridge; containing his new theory of Light and Colours; sent by the Author to the Editor from Cambridge, Feb. 6, 1671-3; to be communicated to the Royal Society. No. 80, p. 3,075.

SIR—To perform my late promise to you, I shall without further ceremony acquaint you that in the beginning of the year 1666 (at which time I applied myself to the grinding of optic glasses of other figures than spherical,) I procured a triangular glass prism, to try therewith the celebrated phenomena of colours. And for that purpose, having darkened my chamber, and made a small hole in my window shuts, to let in a convenient quantity of the sun's light, I placed my prism at this entrance, that it might be thereby refracted to the opposite wall. It was at first a very pleasing diversion to view the vivid and intense colours produced thereby; but after a while applying myself more circumspectly, I was surprised to see them in an oblong form; which according to the received laws of refraction, I expected would have been circular. They were terminated at the sides with straight lines, but at the ends the decay of light was so gradual, that it was difficult to determine justly what was their figure; yet they seemed semicircular.

Comparing the length of this coloured spectrum with its breadth, I found it about five times greater; a disproportion so extravagant, that it excited me to a more than ordinary curiosity of examining from whence it might proceed. I could scarce think that the various thickness of the glass, or the termination with shadow or darkness, could have any influence on light to produce such an effect; yet I thought it not amiss, first to examine those circumstances, and so tried what would happen by transmitting light through parts of the glass of divers thicknesses, or through holes in the window of divers sizes, or by setting the prism without, so that the light might pass through it, and be refracted before it was terminated by the hole; but I found none of these circumstances material. The fashion of the colours was in all these cases the same.

SIR ISAAC NEWTON

Engraving from an original picture by Vanderbank.

Then I suspected, whether by any unevenness in the glass, or other contingent irregularity, these colours might be thus dilated. And to try this, I took another prism like the former, and so placed it, that the light passing through them both, might be refracted contrary ways, and so by the latter returned into that course from which the former had diverted it. For, by this means, I thought the regular effects of the first prism would be destroyed by the second, but the irregular ones more augmented, by the multiplicity of refractions. The event was, that the light, which by the first prism was diffused into an oblong form, was by the second reduced into an orbicular one, with as much regularity as when it did not at all pass through them. So that, whatever was the cause of that length, it was not any contingent irregularity.

I then proceeded to examine more critically, what might be effected by the difference of the incidence of rays coming from divers parts of the sun; and to that end measured the several lines and angles, belonging to the image. Its distance from the hole or prism was 22 feet; its utmost length 13¼ inches; its breadth 2⅝; the diameter of the hole ¼ of an inch; the angle, which the rays, tending towards the middle of the image, made with those lines in which they would have proceeded without refraction, was 44° 56′. And the vertical angle of the prism, 63° 12′. Also the refraction on both sides the prism, that is of the incident and emergent rays, was as near as I could make them equal, and consequently about 54° 4′. And the rays fell perpendicularly upon the wall. Now subducting the diameter of the hole from the length and breadth of the image, there remains 13 inches the length, and 2⅜ the breadth, comprehended, by those rays, which passed through the center of the said hole, and consequently the angle of the hole, which that breadth subtended, was about 31′, answerable to the sun's diameter; but the angle which its length subtended, was more than five such diameters, namely 2° 49′.

Having made these observations, I first computed from them the refractive power of that glass, and found it measured by the ratio of the sizes, 20 to 31. And then, by that ratio, I computed the refraction of two rays flowing from opposite parts of the sun's discus, so as to differ 31′ in their obliquity of incidence, and found that the emergent rays should have comprehended an angle of about 31′, as they did, before they were incident. But because this computation was founded on the hypothesis of the proportionality of the sines of incidence and refraction, which though, by own experience, I could not imagine to be so erroneous as to make that angle but 31′, which in reality was 2° 49′; yet my curiosity caused me again to take my prism. And having placed it at my window, as before, I observed, that by turning it a little about its axis to and fro, so as to vary its obliquity to the light, more than an angle of 4 or 5 degrees, the colours were not thereby sensibly translated from their place on the wall, and consequently by that variation of incidence, the quantity of refraction was not sensibly varied. By this experiment, therefore, as well as by former computation, it was evident, that the difference of the incidence of rays, flowing from divers parts of the sun, could not make them after a decussion, diverge at a sensibly greater angle, than that at which they before converged, which being at most but about 21 or 32 minutes, there still remained some other cause to be found out, from whence it could be 2° 49′.

Then I began to suspect whether the rays, after their trajection through the prism, did not move in curve lines, and according to their more or less curvity tend to divers parts of the wall. And it increased my suspicion, when I remembered that I had often seen a tennis ball, struck with an oblique racket, describe such a curve line. For, a circular as well as a progressive motion being communicated to it by that stroke, its parts on that side, where the motions conspire, must press and beat the contiguous air more violently than on the other, and there excite a reluctancy and reaction of the air proportionately greater. And for the same reason, if the rays of light should possibly be globular bodies, and by their oblique passage out of one medium into another acquire a circulating motion, they ought to feel the greater resistance from the ambient aether, on that side where the motions conspire, and thence be continually bowed to the other. But notwithstanding this plausible ground of suspicion, when I came to examine it, I could observe no such curvity in them. And besides (which was enough for my purpose) I observed, that the difference between the length of the image and the diameter of the hole, through which the light was transmitted, was proportionable to their distance.

The gradual removal of these suspicions at length led me to the experimentum crucis, which was this; I took two boards, and placed one of them close behind the prism at the window, so that the light might pass through a small hole, made in it for that purpose, and fall on the other board, which I placed at about 12 feet distance, having first made a small hole in it also, for some of that incident light to pass through. Then I placed another prism behind this second board, so that the light trajected through both of the boards, might pass through that also, and be again refracted before it arrived at the wall. This done, I took the first prism in my hand, and turned it to and fro slowly about its axis, so much as to make the several parts of the image, cast on the second board, successively pass through the hole in it, that I might observe to what places on the wall the second prism would refract them. And I saw, by the variation of those places, that the light tending to that end of the image, towards which the refraction of the first prism was made, did in the second prism suffer a contraction considerably greater than the light tending to the other end. And so the true cause of the length of that image was detected to be no other, than that light consists of rays differently refrangible, which, without any respect to a difference in their incidence, were according to their degrees of refrangibility, transmitted towards divers parts of the wall.

When I understood this, I left off my aforesaid glass works; for I saw, that the perfection of telescopes was hitherto limited, not so much for want of glasses truly figured according to the prescriptions of optic authors, (which all men have hitherto imagined) as because that light itself is a heterogeneous mixture of differently refrangible rays. So that, were a glass so exactly figured, as to collect any one sort of rays into one point, it could not collect those also into the same point, which having the same incidence upon the same medium are apt to suffer a different refraction. Nay, I wondered, that seeing the difference of refrangibility was so great, as I found it, telescopes should arrive to that perfection they are now at. For measuring the refractions in any one of my prisms, I found, that supposing the common sine of incidence upon one of its planes was 44 parts, the sine of refraction of the utmost rays at the red end of the colours, made out of the glass into the air, would be 68 parts, and the sine of refraction of the utmost rays on the other end 69 parts; so that the difference is about a 24th or 25th part of the whole refraction; and consequently the object glass of any telescope cannot collect all the rays which come from one point of an object, so as to make them convene at its focus in less room than in a circular space, whose diameter is the 50th part of the diameter of its aperture; which is an irregularity, some hundreds of times greater than a circularly fixed lens, of so small a section as the object glasses of long telescopes are, would cause by the unfitness of its figure, were light uniform.

This made me take reflections into consideration, and finding them regular, so that the angle of reflection of all sorts of rays was equal to their angle of incidence; I understood that by their mediation optic instruments might be brought to any degree of perfection imaginable, provided a reflecting substance could be found, which would polish as finely as glass, and reflect as much light as glass transmits, and the art of communicating to it a parabolic figure be also attained. But there seemed very great difficulties, and I have thought them insuperable, when I further considered, that every irregularity in a reflecting superficies makes the rays stray 5 or 6 times more out of their due course, than the like irregularities in a refracting one; so that a much greater curiosity would be here requisite, than in figuring glasses for refraction.

Amid these thoughts I was forced from Cambridge by the intervening plague, and it was more than two years before I proceeded further. But then having thought on a tender way of polishing, proper for metal, whereby as I imagined, the figure also would be corrected to the last; I began to try what might be effected in this kind, and by degrees so far perfected an instrument (in the essential parts of it like that I sent to London,) by which I could discern Jupiter's 4 concomitants, and showed them divers times to two others of my acquaintance. I could also discern the moon-like phase of Venus, but not very distinctly, nor without some niceness in disposing the instrument.

From that time I was interrupted till this last autumn, when I made the other. And that was sensibly better than the first (especially for day objects,) so I doubt not, but they will be still brought to a much greater perfection by their endeavors, who, as you inform me, are taking care about it at London.

I have sometimes thought to make a microscope, which in like manner should have, instead of an object glass, a reflecting piece of metal. And this I hope they will also take into consideration. For those instruments seem as capable of improvement as telescopes, and perhaps more, because but one reflective piece of metal is requisite in them, as you may perceive by the diagram, (fig. 13, pl. 14,) where AB represents the object metal, CD the eye glass, F their common focus, and O the other focus of the metal, in which the object is placed.

But to return from this digression, I told you, that a light is not similar, or homogeneal, but consists of difform rays, some of which are more refrangible than others: so that of those, which are alike incident on the same medium, some shall be more refracted than others, and that not by any virtue of the glass, or other external cause, but from a predisposition, which every particular ray has to suffer a particular degree of refraction.

I shall now proceed to acquaint you with another more notable difformity in its rays, wherein the origin of colours is unfolded; concerning which I shall lay down the doctrine first, and then, for its examination, give you an instance or two of experiments, as a specimen of the rest. The doctrine you will find comprehended and illustrated in the following propositions:

1. As the rays of light differ in degrees of refrangibility, so they also differ in their disposition of light, derived from refractions, or reflections of natural bodies (as it is generally believed,) but original and connate properties, which in divers rays are diverse. Some rays are disposed to exhibit a red colour, and no other: some a yellow, and no other: some a green, and no other, and so of the rest. Nor are there only rays proper and particular to the more eminent colours, but even to all their intermediate gradations.

2. To the same degree of refrangibility ever belongs the same colour, and to the same colour ever belongs the same degree of refrangibility. The least refrangible rays are all disposed to exhibit a red colour, and contrarily, those rays which are disposed to exhibit a red colour, are all the least refrangible: so the most refrangible rays are all disposed to exhibit a deep violet-colour, and contrarily, those which are apt to exhibit such a violet colour, are all the most refrangible. And so to all the intermediate colours, in a continued series, belong intermediate degrees of refrangibility. And this analogy betwixt colours, and refrangibility, is very precise and strict; the rays always either exactly agreeing in both, or proportionally disagreeing in both.

3. The species of colour and degree of refrangibility proper to any particular sort of rays, is not mutable by refraction, nor by reflection from natural bodies, nor by any other cause, that I could yet observe. When any one sort of rays has been well parted from those of other kinds, it has afterwards obstinately retained its colour, notwithstanding my utmost endeavours to change it. I have refracted it with prisms, and reflected it with bodies, which in daylight were of other colours; I have intercepted it with the coloured film of air interceding two compressed plates of glass; transmitted it through coloured mediums, and through mediums irradiated with other sorts of rays, and diversely terminated it; and yet could never produce any new colour out of it. It would by contracting or dilating, become more brisk, or faint, and by

the loss of many rays, in some cases very obscure and dark; but I could never see it change in specie.

4. Yet seeming transmutations of colours may be made, where there is any mixture of divers sorts of rays. For in such mixtures, the component colours appear not, but, by their mutual alloying each other, constitute a middling colour. And therefore, if by refraction, or any other of the aforesaid causes, the difform rays, latent in such a mixture, be separated, there shall emerge colours different from the colour of the composition. Which colours are not new generated, but only made apparent by being parted; for if they be again entirely mixed and blended together, they will again compose that colour, which they did before separation. And for the same reason, transmutations made by the convening of divers colours are not real; for when the difform rays are again severed, they will exhibit the very same colours, which they did before they entered into composition; as you see, blue and yellow powders, when finely mixed, appear to the naked eye green, and yet the colours of the component corpuscles are not thereby really transmuted, but only blended. For, when viewed with a good microscope, they still appear blue and yellow interspersedly.

5. There are therefore two sorts of colours. The one original and simple, the other compounded of these. The original or primary colours are, red, yellow, green, blue, and a violet-purple, together with orange, indigo, and an indefinite variety of intermediate gradations.

6. The same colours in specie with these primary ones may be also produced by composition: for a mixture of yellow and blue makes green; of red and yellow makes orange; of orange and yellowish green makes yellow. And in general, if any two colours be mixed, which in the series of those, generated by the prism, are not too far distant one from another, they by their mutual alloy compound that colour, which in the said series appears in the midway between them. But those which are situated at too great a distance, do not so. Orange and indigo produce not the intermediate green, nor scarlet and green the intermediate yellow.

7. But the most surprising and wonderful composition was that of whiteness. There is no one sort of rays which alone can exhibit this. It is ever compounded, and to its composition are requisite all the aforesaid primary colours, mixed in a due proportion. I have often with admiration beheld, that all the colours of the prism being made to converge, and thereby to be again mixed as they were in the light before it

was incident upon the prism, reproduced light, entirely and perfectly white and not at all sensibly differing from a direct light of the sun, unless when the glasses I used, were not sufficiently clear; for then they would a little incline it to their colour.

8. Hence it therefore comes to pass, that whiteness is the usual colour of light: for, light is a confused aggregate of rays imbued with all sorts of colours, as they are promiscuously darted from the various parts of luminous bodies. And of such a confused aggregate, as I said, is generated whiteness, if there be a due proportion of the ingredients, but if any one predominate, the light must incline to that colour; as it happens in the blue flame of brimstone; the yellow flame of a candle; and the various colours of the fixed stars.

9. These things considered, the manner how colours are produced by the prism is evident. For, of the rays constituting the incident light, since those which differ in colour, proportionally differ in refrangibility, they by their unequal refractions must be severed and dispersed into an oblong form in an orderly succession, from the least refracted scarlet, to the most refracted violet. And for the same reason it is that objects, when looked upon through a prism, appear coloured. For the difform rays, by their unequal refractions, are made to diverge towards several parts of the retina, and there express the images of things coloured, as in the former case they did the sun's image upon the wall. And by this inequality of refractions they became not only coloured, but also very confused and indistinct.

10. Why the colours of the rainbow appear in falling drops of rain, is also from hence evident. For, those drops which refract the rays disposed to appear purple, in greatest quantity to the spectator's eye, refract those of other sorts so much more, as to make them pass beside it; and such are the drops on the exterior part of the primary, and interior part of the secondary bow.

11. The old phenomena of an infusion of lignum nephriticum, leaf gold, fragments of coloured glass, and some other transparently coloured bodies, appearing in one position of one colour, and of another in another, are on these grounds no longer riddles. For, those are substances apt to reflect one sort of light, and transmit another; as may be seen in a dark room, by illuminating them with similar or uncompounded light. For, then they appear that colour only, with which they are illuminated, but yet in one position more vivid and luminous

than in another, accordingly as they are disposed more or less to reflect or transmit the incident colour.

12. From hence also is manifest the reason of an unexpected experiment, which Mr. Hook, somewhere in his micography, relates to have made wtih two wedge-like transparent vessels, filled the one with red, the other with a blue liquor: namely, that though they were severally transparent enough, yet both together became opaque; for, if one transmitted only red, and the other only blue, no rays could pass through them both.

13. I might add more instances of this nature; but I shall conclude with this general one, that the colours of all natural bodies have no other origin than this, that they are variously qualified to reflect one sort of light in greater plenty than another. And this I have experimneted in a dark room, by illuminating those bodies with uncompounded light of divers colours. For, by that means, any body may be made to appear of any colour. They have then no appropriate colour, but ever appear of the colour of the light cast upon them, but yet with this difference, that they are most brisk and vivid in the light of their own day-light colour. Minium appears there of any colour indifferently, with which it is illustrated, but yet most luminous in red; and so bise appears indifferently of any colour with which it is illustrated, but yet most luminous in blue. And therefore minium reflects rays of any colour, but most copiously those indued with red; and consequently when illustrated with daylight, that is, with all sorts of rays promiscuously blended, those qualified with red shall abound most in the reflected light, and by their prevalence cause it to appear of that colour. And for the same reason bise, reflecting blue most copiously, shall appear blue by the excess of those rays in its reflected light; and the like of other bodies. And that this is the entire and adequate cause of their colours, is manifest, because they have no power to change or alter the colours of any sort of rays, incident apart, but put on all colours indifferently, with which they are enlightened.

These things being so, it can be no longer disputed, whether there be colours in the dark, nor whether they be the qualities of the objects we see, no nor perhaps whether light be a body. For since colours are the qualities of light, having its rays for their entire and immediate subject, how can we think those rays qualities also, unless one quality may be the subject of and sustain another; which in effect is to call it a substance. We should not know bodies for substances, were it not for their sensible qualities, and the principal of those being now found due to something else, we have as good reason to believe that to be substance also.

Besides, whoever thought any quality to be a heterogenous aggregate, such as light is discovered to be. But to determine more absolutely what light is, after what manner refracted, and by what modes or actions it produces in our minds the phantasms of colours, is not so easy. And I shall not mingle conjectures with certainties.

Reviewing what I have written, I see the discourse itself will lead to divers experiments sufficient for its examination, and therefore I shall not trouble you further, than to describe one of those which I have already insinuated.

In a darkened room make a hole in the shut of a window, whose diameter may conveniently be about a third part of an inch, to admit a convenient quantity of the sun's light; and there place a clear and colourless prism, to refract the entering light towards the further part of the room, which, as I said, will thereby be diffused into an oblong coloured image. Then place a lens of about three feet radius (suppose a broad object glass of a three-foot telescope,) at the distance of about four or five feet from thence, through which all those colours may at once be transmitted, and made by its reflection to convene at a further distance of about ten or twelve feet. If at that distance you intercept this light with a sheet of white paper, you will see the colours converted into whiteness again by being mingled. But it is requisite that the prism and lens be placed steady, and that the paper on which the colours are cast be moved to and fro; for by such motion, you will not only find at what distance the whiteness is most perfect, but also see how the colours gradually convene, and vanish into whiteness, are again dissipated and severed, and in an inverted order retain the same colours which they had before they entered into the composition. You may also see, that if any of the colours at the lens be intercepted, the whiteness will be changed into the other colours. And therefore that the composition of whiteness be perfect, care must be taken that none of the colours fall beside the lens.

In the annexed design of this experiment, ABC expresses the prism set endwise to sight, fig. 14, pl. 14, close by the hole F of the window E.G. Its verticle angle ACB may conveniently be about 60 degrees: MN designs the lens. Its breadth 2½ or 3 inches. SF one of the straight lines, in which difform rays may be conceived to flow successively from the sun. FP and FR two of those rays unequally refracted, which the lens makes to converge towards Q, and after decussation to diverge again. And HI the paper, at divers distances, on which the colours are projected; which in Q constitutes whiteness, but are red and yellow in R, r, and S, and blue and purple in P, p, and w.

If you proceed further to try the impossibility of changing any uncompounded colour, (which I have asserted in the 3d and 13th propositions) it is requisite that the room be made very dark, least any scattering light mixing with the colour disturb and alloy it, and render it compound, contrary to the design of the experiment. It is also requisite, that there be a perfecter separation of the colours than, after the manner above described, can be made by the refraction of one single prism, and how to make such further separations, will scarcely be difficult to them that consider the discovered laws of refractions. But if trial shall be made with the colours not thoroughly separated, there must be allowed changes proportionable to the mixture. Thus, if compound light fall upon blue bise, the bise will not appear perfectly yellow, but rather green, because there are in the yellow mixture many rays indued with green, and green being less remote from the usual colour of bise than yellow, is the more copiously reflected by it.

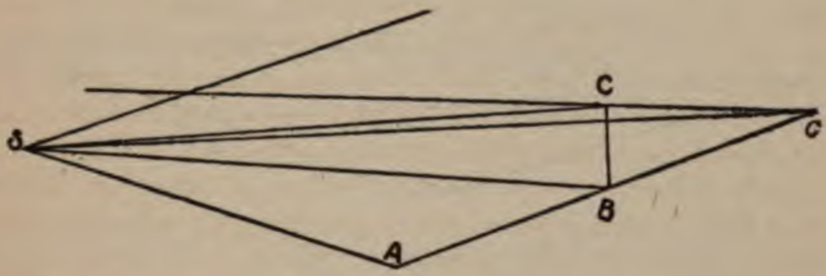
In like manner, if any one of the prismatic colours, suppose red, be intercepted, on design to try the asserted impossibility of reproducing that colour out of the others which are pretermitted; it is necessary, either that the colours be very well parted before the red be intercepted, or that together with the red the neighbouring colours, into which the red is secretly dispersed, (that is, the yellow, and perhaps green too) be intercepted, or else, that allowance be made for the emerging of so much red out of the yellow green, as may possibly have been diffused, and scatteringly blended in those colours. And if these things be observed, the new production of red, or any intercepted colour will be found impossible.

This I conceive is enough for an introduction to experiments of this kind; which if any of the Royal Society shall be so curious as to prosecute, I should be very glad to be informed with what success: that, if anything seem to be defective or to thwart this relation, I may have an opportunity of giving further direction about it, or of acknowledging my errors, if I have committed any.

THE THEORY OF GRAVITATION

Proposition I. Theorem I.

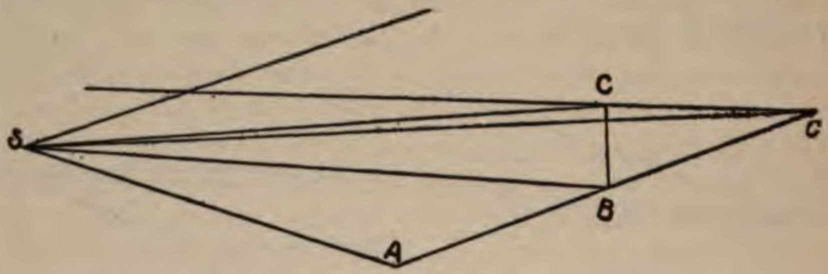
That the areas, which bodies, when moving in curves, cut off by radii drawn to a fixed center of force, are in one fixed plane and are proportional to the times.



Let the time be divided into equal parts, and in the first period of time let the body driven by one force describe the line AB. In the second period, it would, if nothing hindered it, go on to c, describing the line Bc equal to AB. Then by the radii AS, BS, cS to the center S would be cut off the equal areas ASB, BSc [the bases being equal and the altitude the same]. Now when the body comes to B, a centripetal force [in the direction BS] acts upon it with uniform impulse, and makes it leave the line of direction Bc and pass along the line BC. Let cC be drawn parallel to the direction of the force BS, meeting BC in C. Then at the end of the second (equal) period the body will be found at C, in the same plane with the triangle ASB. Draw SC. Then the triangle SBC, on account of the parallels SB and cC, will be equal to the triangle SBc and therefore to the triangle SAB, etc.—Therefore in equal times equal areas will be described in the same plane.—Let the number of the triangles be increased and their altitude diminished to infinity: their ultimate perimeter will be a curve (Cor. iv. Lem. iii.). And therefore a centripetal force, by which a body is continually drawn from a course tangent to this curve, will act along this radius and whatever areas have been described proportional to the times, will remain proportional to the same times when curvilinear.

PROPOSITION II. THEOREM II.

Every body, which is moved in any curve described in a plane, and cuts off, by radii drawn to a center that is stationary or moving in a straight line with uniform motion, areas about the center proportional to the times, is drawn by a centripetal force urging it toward the center.



For every body that is moved in a curved line, is turned from its course by some force acting upon it. And that force by which a body is turned from a straight line, and is made to describe the supposed equal triangles SAB, SBC, etc., about the fixed center S in equal times must act at the point B in a line parallel to Cc.

[For extend AB to c making AB=Bc. Then c is where the body would have been had it not been drawn by the new force at B. Hence at B the force acts in the direction Cc.]

But cC is parallel to BS. [For since the triangle SCB = triangle SAB by hypothesis, and triangle SAB = SBc (equal altitude and bases) then triangles SBC and SBc must be equal and Cc and SB must be parallel, in order to have the altitude equal.] Therefore at B the force acts along the line BS toward the center S. Therefore the force always acts toward the immovable center S.

[It will be remembered that Kepler had already shown that the planets move in ellipses, and do cut off areas proportioned to the times. Hence they act as if drawn by a centripetal force. Then what is this force? The next great step was to prove it identical with weight.]

PROPOSITION IV. THEOREM IV.

That the moon is drawn by gravity [*weight*] *toward the earth, and is deflected by the force of gravity from a straight line* [*tangent*], *and thus held in her orbit.*

The mean distance of the moon from the earth in terms of semi-diameters of the earth is, according to Ptolemy and many astronomers, 59; according to Vendelius and Huyghens, 60; according to Copernicus, 60 1-5; according to Streetus, 60 2-5, and according to Tycho, 56 1-2. (But Tycho has erred......) Let us assume that the mean distance is 60 semi-diameters of the earth. The moon completes her full periodic times (goes round the earth) in 27 days, 7 hours, 43 minutes, as is determined by astronomers. The circumference of the earth is 123,249,600 Paris feet, as has been calculated by the French measurements. If the moon should be deprived of every other motion, and drawn by that one alone by which she is held in her orbit, she would fall to the earth. The distance she would fall in the first minute would be 15 1-12 Paris feet. This follows from calculation or from Proposition xxvi., Bk. I., or (what amounts to the same thing) from Cor. ix., Prop. iv., the same Book. For the versed sine (distance along the radius from the chord to the circumference) of that arc which the moon describes in one minute at her mean motion and at a distance of 60 semi-diameters of the earth from the earth is about 15 1-2 Paris feet, or, more accurately, 15 feet, 1 inch, and 1 4-9 lines. [This is found as follows: The distance of the moon from the earth is 60 radii of the earth. Hence the orbit of the moon equals 60 times the circumference of the earth. Divide this result by the number of minutes (39,343) in the moon's periodic time, and the quotient is the arc passed over by the moon in one minute (about 187,964 Paris feet). In the diagram Mm is the arc passed over by the moon in one minute, Mx is the distance the moon has been deflected from a tangent in one minute and the distance she would fall toward the earth in this time if acted on by gravity alone. Arc Mm squared equals Mx times MA (diameter moon's orbit), or $Mx = Mm^2$ divided by MA, or 35,330,465,296 feet divided by 2,353,893,976 or 15 1-12 feet.]

Now since this force in approaching the earth increases in inverse ratio with the square of the distance, therefore at the surface of the earth it will be greater by 60x60 than at the moon [the distance being 60 radii of the earth]. Then a body driven by this force in falling in our locality ought to pass over in the first minute 60x60x15 1-12 Paris feet, and in the space of one second 15 1-12 Paris feet or, more accurately 15 feet, 1 inch, and 1 4-9 lines. But heavy bodies do actually fall at this rate on the earth. For the length of a pendulum, oscillating each second in the latitude of Lutetia, Paris, is three Paris feet and 8 1-2 lines, as Huyghens has observed, and the distance which a body falls in a second when pulled by gravity is to the length of such a pendulum as the square of the circumference of a circle to its diameter, as Huyghens has also observed; and this is 15 Paris feet, 1 inch, 1 7-9 lines. Hence the force by which the moon is held in its orbit, if it were brought down upon earth, would be equal to the force of gravity among us, and hence is that very force which we are wont to call (weight or) gravity.

Book III. Proposition V. Theorem V. Scholium

The force which retains the celestial bodies in their orbits has been hitherto called centripetal force; but it being now made plain that it can be no other than a gravitating force, we shall hereafter call it gravity. For the cause of that centripetal force which retains the moon in its orbit will extend itself to all the planets.

Book III. Proposition VI. Theorem VI.

That all bodies gravitate towards every planet; and that the weights of bodies towards any the same *planet, at equal distances from the centre of the planet, are proportional to the quantities of matter which they severally contain.*

It has been, now of a long time, observed by others, that all sorts of heavy bodies (allowance being made for the inequality of retardation which they suffer from a small power of resistance in the air) descend to the earth *from equal heights* in equal times; and that equality of times we may distinguish to a great accuracy, by the help of pendulums. I tried the thing in gold, silver, lead, glass, sand, common salt, wood, water, and wheat. I provided two wooden boxes, round and equal; I filled the one with wood, and suspended an equal weight of gold (as exactly as I could) in the centre of oscillation of the other. The boxes hanging by equal threads of 11 feet made a couple of pendulums perfectly equal in weight and figure, and equally receiving the resistance of the air. And, placing the one by the other, I observed them to play together forwards and backwards, for a long time, with equal vibrations. . . . and the like happened in the other bodies. By these experiments, in bodies of the same weight, I could manifestly have discovered a difference of matter less than the thousandth part of the whole, had any such been. But, without all doubt, the nature of gravity towards the planets is the same as towards the earth. . . . Moreover, since the satellites of Jupiter perform their revolutions in times which observe the sesquiplicate proportion of their distances from Jupiter's centre—that is, equal at equal distances. And, therefore, these satellites, if supposed to fall *towards Jupiter* from equal heights, would describe equal spaces in equal times, in like manner as heavy bodies do on our earth. . . . If, at equal distances from the sun, any satellite, in proportion to the quantity of its matter, did gravitate towards the sun with a force greater than Jupiter in proportion to his, according to any given proportion, suppose of *d* to *e;* then the distance between the centres of the sun and of the satellite's orbit would be always greater than the distance between the centres of the sun and of Jupiter nearly in the sub-duplicate of that proportion; as by some computations I have found. And if the satellite did gravitate towards the sun with a force, lesser in the proportion of *e* to *d,* the distance of the centre of the satellite's orbit from the sun would be less than the distance of the centre of Jupiter from the sun in the sub-duplicate of the same proportion. Therefore if, at equal distances from the sun, the accelerative gravity of any satellite towards the sun were greater or less than the accelerative gravity of Jupiter towards the sun but one 1-1000 part of the whole gravity, the distance of the centre of the satellite's orbit from the sun would be greater or less than the distance of Jupiter from the sun by one 1-2000 part of the whole distance—that is, by a fifth part of the distance of the utmost satellite from the centre of Jupiter; an eccentricity of the orbit which would be very sensible. But the orbits of the satellite are concentric to Jupiter, and therefore the accelerative gravities of Jupiter, and of all its satellites towards the sun, are equal among themselves. . .

But further; the weights of all the parts of every planet towards any other planet are one to another as the matter in the several parts; for if some parts did gravitate more, others less, than for the quantity of their matter, then the whole planet, according to the sort of parts with which it most abounds, would gravitate more or less than in proportion to the quantity of matter in the whole. Nor is it of any moment whether these parts are external or internal; for if, for example, we should imagine the terrestrial bodies with us to be raised up to the orb of the moon, to be there compared with its body; if the weights of such bodies were to the weights of the external parts of the moon as the quantities of matter in the one and in the other respectively; but to the weights of the internal parts in a greater or less proportion, then likewise the weights of those bodies would be to the weight of the whole moon in a greater or less proportion; against what we have showed above.

Cor. 1. Hence the weights of bodies do not depend upon their forms and textures; for if the weights could be altered with the forms, they would be greater or less, according to the variety of forms, in equal matter; altogether against experience.

Cor. 2. Universally, all bodies about the earth gravitate towards the earth; and the weights of all, at equal distances from the earth's centre, are as the quantities of matter which they severally contain. This is the quality of all bodies within the reach of our experiments; and therefore (by rule 3) to be affirmed of all bodies whatsoever. . . .

Cor. 5. The power of gravity is of a different nature from the power of magnetism; for the magnetic attraction is not as the matter attracted. Some bodies are attracted more by the magnet; others less; most bodies not at all. The power of magnetism in one and the same body may be increased and diminished; and is sometimes far stronger, for the quantity of matter, than the power of gravity; and in receding from the magnet decreases not in the duplicate but almost in the triplicate proportion of the distance, as nearly as I could judge from some rude observations.

Book III. Proposition VII. Theorem VII.

That there is a power of gravity tending to all bodies, proportional to the several quantities of matter which they contain.

That all the planets mutually gravitate one towards another, we have proved before; as well as that the force of gravity towards every one of them, considered apart, is reciprocally as the square of the distance of places from the centre of the planet. And thence (by prop. 69, book I, and its corollaries) it follows, that the gravity tending towards all the planets is proportional to the matter which they contain.

Moreover, since all the parts of any planet A gravitate towards any other planet B; and the gravity of every part is to the gravity of the whole as the matter of the part to the matter of the whole; and (by law 3) to every action corresponds an equal reaction; therefore the planet B will, on the other hand, gravitate towards all the parts of the planet A; and its gravity towards any one part will be to the gravity towards the whole as the matter of the part to the matter of the whole. Q. E. D.

Cor. 1. Therefore the force of gravity towards any whole planet arises from, and is compounded of, the forces of gravity towards all its parts. Magnetic and electric attractions afford us examples of this; for all attraction towards the whole arises from the attractions towards the several parts. The thing may be easily understood in gravity, if we consider a greater planet as formed of a number of lesser planets meeting together in one globe; for *hence it would appear that* the force of the whole must arise from the forces of the component parts. If it is objected that, according to this law, all bodies with us must mutually gravitate one towards another, I answer, that since the gravitation towards these bodies is to the gravitation towards the whole earth as these bodies are to the whole earth, the gravitation towards them must be far less than to fall under the observation of our senses.

Cor. 2. The force of gravity towards the several equal particles of any body is reciprocally as the square of the distance of places from the particles; as appears from cor. 3, prop. 74, book I.

[*Under Proposition X. is the following important passage:*] However the planets have been formed while they were yet in fluid masses, all the heavier matter subsided to the centre. Since, therefore, the common matter of our earth on the surface thereof is about twice as heavy as water, and a little lower, in mines, is found about three, or four, or even five times more heavy, it is probable that the quantity of the whole matter of the earth may be five or six times greater than if it consisted all of water.—Translated from the "Principia."

HUYGHENS

Christian Huyghens was born at The Hague, April 14, 1629. He studied law in Breda, but became interested in mathematics and neglected his law for it. In 1655 he improved on the method of grinding telescopic lenses, and with his brother Constantine discovered the sixth satellite of Saturn and the fact that it was surrounded by rings.

In 1657 he presented the first pendulum-clock to the states-general. The years 1665 to 1681 he spent in France at the "Library of the King." During this time he determined the relation between the length and time of oscillation of the pendulum, and solved the problem of the center of oscillation. In 1678 he had thought out his wave theory of light and in 1690 published it at Leyden.

He died at The Hague, June 8, 1695.

THE WAVE THEORY OF LIGHT

Proofs in optics, as in every science in which mathematics is applied to matter, are founded upon facts from experience—as for example, that light moves in straight lines, that the angles of incidence and reflection are equal, and that light rays are refracted in accordance with the law of sines [i. e., that the ratio between the sines of the incident and refracted ray is constant for the same substance.] For this last law is now as generally and surely known as either of the others.

Most writers in optics have been content to assume these facts, but others more curious have attempted to discover the source and reason of these phenomena, looking upon them as being in themselves interesting data. Yet although they have propounded some ingenious theories, intelligent readers still require a fuller explanation before being entirely satisfied. Therefore I herein offer some considerations on the matter with the hope of making clearer this branch of physics which has not improperly gained the reputation of being very obscure.

I feel myself particularly indebted to those that first began to study these profound subjects, and to lead us to hope them capable of orderly explanation. Yet I have been surprised to find these very investigators accepting arguments far from clear as if proof conclusive. No one has yet offered even a probable explanation of the first two remarkable phenomena of light,—why it moves in straight lines, and why rays from any and all directions can cross one another without interference.

I shall attempt in this treatise to submit clearer and more probable reasons, along the lines of modern philosophy, first for the transmission of light, and, second, for its reflection when it meets certain bodies.

Further, I shall explain the fact of rays said to undergo refraction in passing through various transparent bodies. Here I shall consider also, the refractions due to the differing densities of the atmosphere. Later I shall investigate the remarkable refraction occurring in Icelandic crystals. Finally, I shall study the different shapes necessary in transparent and reflecting bodies in order to bring together rays upon a single point or to deflect them in different ways. Here we shall see how easy it is by our new theory to determine not alone the ellipses, hyperbolas, and other curves which M. Descartes has so shrewdly constructed for this end, but as well the curve that one surface of a lens must have when the other surface is known, as spherical, plane, or any other figure.

We cannot but believe that light is the motion of a certain material. Thus when we reflect on its production, we discover that here on the earth it is usually emitted from fire and flame, and that these unquestionably contain bodies in rapid motion, since they can soften and melt many other more solid substances. If we note its effects, we see that when light is brought to a point, as, for example, by concave mirrors, it can cause combustion the same as fire: that is, it can force bodies apart, a power that certainly argues motion, at least in that true science where one believes all natural phenomena to result from mechanical causes. Moreover, in my mind we must either admit this or give up all hope of ever understanding anything in natural science.

Since, according to this philosophy, it is believed certain that the sensation of sight is produced only by the impulse of some form of matter against the nerves at the base of the eye, we have yet another reason for believing light to be a motion in the substance lying between us and the body producing the light.

As soon as we consider, moreover, the enormous speed with which light travels in every direction, and the fact that when rays come from different directions, even from those exactly opposite, they cross without interference, it must be plain that we do not see luminous objects by means of particles transmitted from the objects to us, as a shot or an arrow moves through the air. For surely this would not allow for the two qualities of light just mentioned, particularly the latter (that of speed). Light, then, is transmitted in some other way, a comprehension of which we may get from our knowledge of how sound moves through the air.

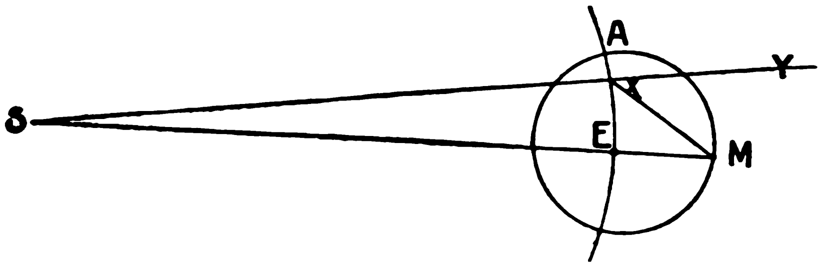
We know that sound is sent out in all directions through the medium of the air, a substance invisible and impalpable, by means of a motion that is communicated successively from one part of the air to the next; and as this movement has the same speed in all directions, it must form spherical surfaces that keep enlarging until at last they strike the ear. Now there can be no doubt that light likewise reaches us from a luminous substance through some motion caused in the matter lying in the intervening space,—for we have seen above that this cannot take place through the transmission of matter from one place to another.

If, moreover, light requires time for its passage—a matter we shall discuss in a moment—it will then follow that this movement is caused in the substance gradually. and therefore is transmitted, like sound, by surfaces and spherical waves. I call these *waves* because of their likeness to those formed when one throws a pebble into water, which are examples of gradual propagation in circles. although from a different cause and on a plane surface.

In regard to the question of light requiring time for its transmission, let us consider whether there is any experimental evidence against it.

What experiments we can make here on the earth with sources of light placed at great distances (although indicating that it does not take a sensible time for light to pass over these distances) are subject to the objection that these distances are yet too small. and that we can only argue that the movement of light is enormously fast. M. Descartes thought it to be instantaneous and based his opinion upon much better reasons taken from the eclipse of the moon. Yet as I shall make clear, even this evidence is not decisive. I shall state the matter in a somewhat different way from his in order to more easily exhibit all the consequences.

Suppose S to be the position of the sun, E A part of the orbit of the earth, S E M a straight line intersecting in M, the orbit of the moon, represented by the circle A M.



Now if light requires time—say an hour—to move the distance between the earth and the moon, then [at the time of an eclipse] it follows that when the earth has come to E its shadow, or the stoppage of the light of the sun, will not yet have reached M [the moon], and will not for an hour. Counting from the instant the earth reaches E, it will be an hour before will reach M if it is to be obscured there. This eclipse will not be seen from the earth for yet another hour. Suppose that during these two hours the earth has moved to X, the moon appearing eclipsed at M, the sun still being seen at S. For I assume as does Copernicus that the sun is fixed and since light moves in straight lines, is always seen in its true position.

But as a matter of fact, we are assured that the eclipsed moon always appears directly opposite the sun; while on the above supposition [that light takes an hour in passing between the moon and the earth], its position ought to be back of the straight line by the angle Y X M, the supplement of the angle S X M. But this is not the case, for this angle Y X M would be very easily noticed, it being about 33 degrees. For by our analysis (found in the essay on the causes of the phenomena of Saturn), the distance from the sun to the earth, S E, is about 12,000 times the diameter of the earth, and hence 400 times the distance of the moon, which is 30 diameters. The angle X M E then will be nearly 400 times as great as E S X, which is 5 minutes, i. e., the angular distance travelled by the earth in two hours [the earth traversing almost a degree in a day]. Thus the angle E M X is almost 33 degrees, and likewise the angle M X Y, being 5 minutes greater [than E M X].

Now it must be remembered that in this computation it is assumed that the speed of light is such as to consume an hour in passing from here to the moon. But if we assume it to take only a minute of time, then the angle Y X M would amount to only 33 minutes, and if it only takes ten seconds, this angle will be less than six minutes. Now so small an angle is not observable in a lunar eclipse and hence it is not permissible to argue that light is absolutely instantaneous.

It is rather unusual, we admit, to take for granted a speed 100,000 times as great as that of sound, which (following my experiments) travels about 180 toises [about 1150 feet] in a second, or during a pulse-beat. Yet this supposition is not at all impossible, for it is not necessary to carry a body at such speed but only for motion to traverse successively from one point to another.

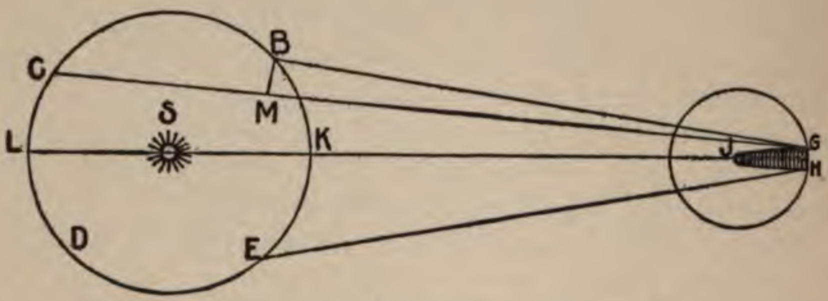
Hence I do not hesitate in this matter to assume that the passage of light takes time, for on this assumption all phenomena can be explained, while on the contrary supposition none of them can be explained. In fact, it seems to me and to many others as well, that M. Descartes, whose purpose has been to discuss all physical matters clearly, and who has certainly succeeded in this better than any one before him, has written nothing on light and its qualities that is not either hard to understand or even incomprehensible.

Moreover, this idea that I have propounded as an hypothesis has lately been made a well nigh established fact by that keen calculation of

Roemer, whose method I will here take occasion to describe, on the expectation that he will himself in the future fully confirm this theory.

His method, the same as the one we have just discussed, is astronomical. He shows not only that light takes time for its passage, but calculates also its speed and that this must be at least six times as much as the rate I have just given as an estimate.

In his demonstration he uses the eclipses of the small satellites that revolve around Jupiter, and very frequently pass into his shadow. Roemer's reasoning is this:



Let S be the sun, B C D E the yearly orbit of the earth, J Jupiter and G H the orbit of his nearest satellite, for this one because of its short period is better suited to this investigation than any one of the other three. Suppose G to be the point where the satellite enters, and H where it leaves, Jupiter's shadow.

Suppose that when the earth is at B, the satellite is seen to emerge [at G], at some time before the last quarter. Were the earth to remain stationary there, 42½ hours would elapse before the next emergence would take place, for this much time is taken by the satellite in making one revolution in its orbit and returning to opposition to the sun. For example, if the earth remained at B during 30 revolutions, then after 30 times 42½ hours, the satellite would again be seen to emerge. If in the meantime the earth has moved to C, farther from Jupiter, it is clear that if light requires time for its passage, the emergence of the satellite will be seen later when the earth is at C than when at B. For we must add to the 30 times 42½ hours, the time occupied by light in passing over the difference between the distances [of the earth from Jupiter] G B and G C, i. e., M C. So in the other quarter, when the earth travels from D to E, approaching Jupiter, the eclipses will occur earlier when the earth is at E than when at D.

Now by many observations of these eclipses throughout ten years, it is shown that these inequalities are actually of some moment, amounting to as much as ten minutes or more: whence it is argued that in traversing the whole diameter of the earth's orbit, K L, double the distance from the earth to the sun, light takes about 22 minutes.

The motion of Jupiter in its orbit while the earth passes from B to C or from D to E has been taken into consideration in Roemer's calculation, where it is also proved that these inequalities cannot be caused by any irregularity or eccentricity in the movement of the satellite.

Now if we consider the enormous size of this diameter K L [the earth's orbit] which I have estimated to be about 24,000 times that of the earth, we get some comprehension of the extraordinary speed of light.

Even if K L were only 22,00c diameters of the earth, a speed traversing this distance in 22 minutes would be equal to the rate of a thousand diameters a minute, i. e., 16 2-3 diameters a second (or a pulse-beat) which makes more than 1,100 times 100,000 toises, since one diameter of the earth equals 2,865 leagues, of which there are 25 to the degree, and since in accordance with the very precise calculation made by Mr. Picard in 1669 under orders from the king, each league contains 2,282 toises.

As I stated before sound moves only 180 toises per second. Hence the speed of light is over 600,000 times as great as that of sound, which, however, is very different from being instantaneous,—it is the difference between any finite number and infinity. The theory that light movements are propagated from point to point in time being thus demonstrated, it follows that light moves in spherical waves, as does sound.

But if they are alike in this regard, they are unlike in others, as in the original cause of the motion that transmits them, the medium through which they move, and the manner in which they are transmitted in it.

We know that sound is caused by the rapid vibration of some body (either as a whole or in part), this vibration setting in motion the adjoining air. But light movements must arise at every point of the luminous body, otherwise all the various parts of the body would not be visible. This fact will be clearer from what follows.

In my judgment, this movement of light-giving bodies cannot be more satisfactorily explained than by supposing that those that are fluid, e. g., a flame, and probably the sun and stars, consist of particles that float about in a much rarer medium, that sets them in violent motion, causing them to strike against the still more minute particles of the surrounding ether. In the case of light-giving solids such as red-hot metal or carbon we may suppose this movement to be caused by the rapid motions of the metal or wood, the particles on the surface exciting the ether. Hence the vibration producing light must be much shorter and faster than that causing sound, since we do not find that sound disturbances give rise to light any more than the wave of the hand through the air causes sound.

The next question is in regard to the nature of the medium through which the vibration produced by light-giving bodies moves. I have named it *ether,* but it plainly differs from the medium through which sound moves. The latter is simply the air we feel and breathe, and when it is removed from any space, the medium which carries light still remains. This is shown by surrounding the sounding body in a glass vessel, and exhausting the air by means of the air-pump that Mr. Boyle has devised, and with which he has performed so many striking experiments. In trying this experiment, however, it is best to set the sounder on cotton or feathers so that it cannot communicate vibrations to the glass receiver or the air-pump, a point hitherto neglected. Then, when all the air has been exhausted, one catches no sound from the metal when it is struck.

Hence we conclude not only that our atmosphere which cannot penetrate glass is the medium through which sound acts, but that the medium carrying light-vibrations is something different: for after the vessel is exhausted of air, light passes through it as easily as before.

The last point is proven even more conclusively by the famous experiment of Torricelli. [Fill a long closed glass tube with mercury, then invert it.] The top of the glass tube not filled by the mercury contains a high vacuum, but transmits light as well as when filled with air. This demonstrates that there is within the tube some form of matter different from air, and which penetrates either glass or mercury, or both, though both are impenetrable to air. And if a like experiment is tried with a little water on top of the mercury, it becomes equally clear that the substance in question traverses either glass or water or both.

In regard to the different methods of transmission of sound and light, in the case of sound it is easy to see what happens when one remembers that air can be compressed and reduced to a much smaller volume than usual, and that it tends with the same force to expand to its original volume. This quality, considered along with its penetrability retained in spite of such condensation seems to show that it consists of small particles that float about in rapid vibration in an ether consisting of still more minute particles. Sound, then, is caused by the struggle of these particles to escape when at any point in the course of a wave they are more crowded together than at some other point.

Now the wonderful speed of light considered with its other qualities, does not permit us to believe it to be transmitted in the same manner. Therefore I shall try to explain the way in which I think it must take place. I must first, however, describe that quality of hard substances through which they transmit motion one to another. If one take a number of balls of the same size of any hard substance, and place them touching one another in one line, he will find that on letting a ball of the same size strike against one end of the line, the motion is transmitted in an instant to the other end of the line. The last ball is driven from the line while the others are apparently undisturbed, the ball that struck the line coming to a dead stop. This is an illustration of a transmission of motion at great speed, varying directly as the hardness of the balls. Yet it is certain that this transmission is not instantaneous, but requires time. For if the movement, or if you wish, the tendency to move, did not pass from one ball to another in succession, they would all be set in motion at the same instant and would all move forward at the same time. Now this is so far from the case that only the last one leaves the row, and it has the speed of the ball that first struck the line.

There are other experiments, also demonstrating that all bodies, even those thought hardest, such as steel, glass and agate, are really elastic, and bend a little, no matter whether they are in rods, balls, or bodies of any other shape,—that is, they give slightly at the point where struck, and at once regain their former shape. Thus I have discovered that in letting a glass or agate ball strike on a large, thick, flat piece of the same substance the surface of which has been roughened by the breath, the place where it strikes is shown by a circular indentation that varies in size directly as the force of the blow. This indicates that the materials give when struck and then fly back,—an event that necessarily takes time.

Now to apply such a motion to the explanation of light, there is nothing in the way of our imagining the particles of ether to have an almost complete hardness, and an elasticity as perfect as we need wish.

We need not here discuss the cause of either this hardness of elasticity, as this would lead us too far from the question at issue. I will remark, however, by the way, that these particles of ether, in spite of their minuteness, are also composed of parts and that their elasticity depends on a very rapid motion of a subtle substance traversing them in all directions and making them take a structure that offers a ready passage to this fluid. This agrees with the idea of M. Descartes, except that I would not, like him, give the pores the shape of round, hollow canals. This is so far from being at all absurd or incomprehensible that it is easily credible that nature uses an infinite series of different-sized molecules in order to produce her marvelous effects.

Moreover, although we do not know the cause of elasticity, we cannot have failed to notice that most bodies possess this characteristic; hence it is not unreasonable to suppose that it is a quality of the minute, invisible particles of the ether. And it is a fact that if one looks for some other method of accounting for the gradual transmission of light, he will have a hard time finding any supposition better suited than elasticity to explain the fact of uniform speed. This [uniform speed] seems to be a necessary assumption, for if the motion slowed down when distributed over a great mass of matter at a far distance from its source, then this great speed would at last be lost. On the other hand, we suppose ether to have the property of elasticity so that its particles regain their shape with equal activity whether struck a hard or gentle blow. Thus the rate at which light would move would remain constant.

TRANSLATED FROM TRAITE′ DE LA LUMIERE.

THE BEGINNING OF CHEMISTRY

As ASTROLOGY was the forerunner of astronomy, so the herald of chemistry was alchemy. In ancient times alchemy went hand in hand with astrology in studying the hidden influences had by the spirits of the heavens and earth over mortals.

Alchemists believed all things to live, and the gases they had learned to drive out of such compounds as red oxide of mercury to be the spirits—the living souls—of these substances. They had not learned to put the wide gulf which we do between life and matter, the spiritual and the material, the supernatural and the natural, but thought all things living, spiritual, and natural. "Everything, even heaven and hell, are of this earth," says the pseudo-Plato. Hence alchemy puzzled itself over the transmutation of metals, the philosopher's stone, the influence of the spirits of things over health, the elixir of life and the like. Yet most of the best known doctors of the Middle Ages, such as Geber, Avicenna, Aviceborn and Roger Bacon, were alchemists, and the first great represenative of medicine in modern times, Paracelsus, was another. It was Paracelsus (1493-1541) who gave alchemy its most useful bent,—"the true use of chemie," says he, "is not to make gold, but medicines."

The Arabians had discovered some of the acids. Paracelsus found the medicinal use of antimony. Glauber (1604-1668) first made artificially sulphate of sodium, called Glauber's salt, and describes other sulphates and chlorides. He thought mercury and salt to be the principles of all things.

Robert Boyle (1627-1691) examined the influence of pressure on air and developed his law that (the temperature remaining the same) the volume of air (or gas) varies inversely as the pressure. By this time the idea that the gases in things are living souls was pretty well overthrown.

Stahl (1660-1734) advanced the idea that all combustion is the driving off of a fire-element, phlogiston. This theory accounted for many facts and was not refuted for a century. He admitted water, acid, earth and phlogiston as elements.

Robert Hooke in 1665 had set forward the opinion that air contains a substance such as in saltpetre. Mayow (1645-1679), as stated elsewhere, experimented on common air, and separated the "breathing or fire-air" from the rest.

Joseph Black in the latter part of the eighteenth century showed that magnesia and lime weigh less after being heated than before, and that this is because of the expulsion from them of a "fixed air" (carbon dioxide). He found, too, that they would absorb a large amount of heat which became insensible to the touch. This heat he called "latent."

His experiments bring us directly to the work of Priestley, Cavendish and Lavoisier, and the beginning of scientific chemistry.

BOYLE

Robert Boyle was the fourteenth child of the Earl of Cork and was born in Munster, Ireland, January 25, 1627. His education was received at Eton, at Stallbridge under the rector, and under private tutors while travelling. His father died in 1644 and left him the Irish estates. In 1645 he became one of a group of scientists which afterwards (1663) developed into the Royal Society. The rest of his life was spent mostly in scientific research. He made many experiments with the air-pump invented by Guericke on the relation of air to life. Most of his work was in breaking ground in the newer fields of physics and chemistry. Probably the most definite result reached by him was his Law of Compressibility of Gases that the expansion of a gas is practically in inverse ratio to the pressure upon it.

He died December 30, 1691.

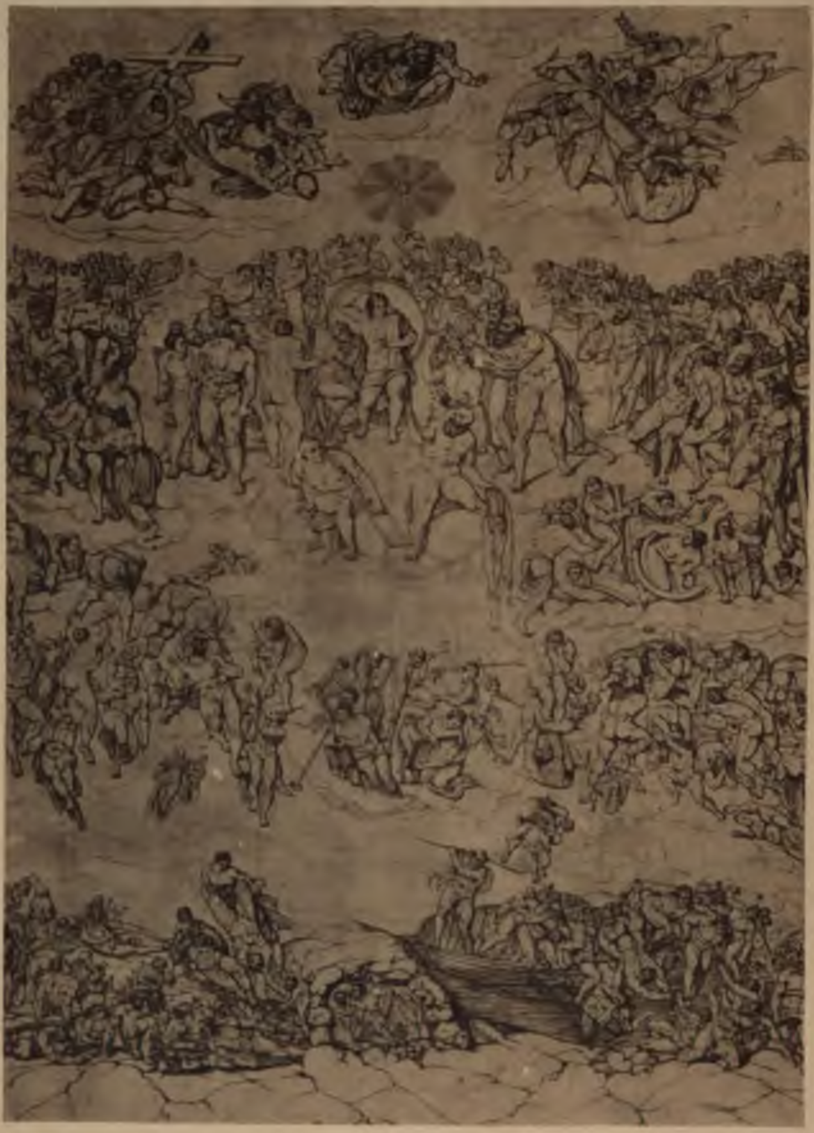
The Discovery of His Law

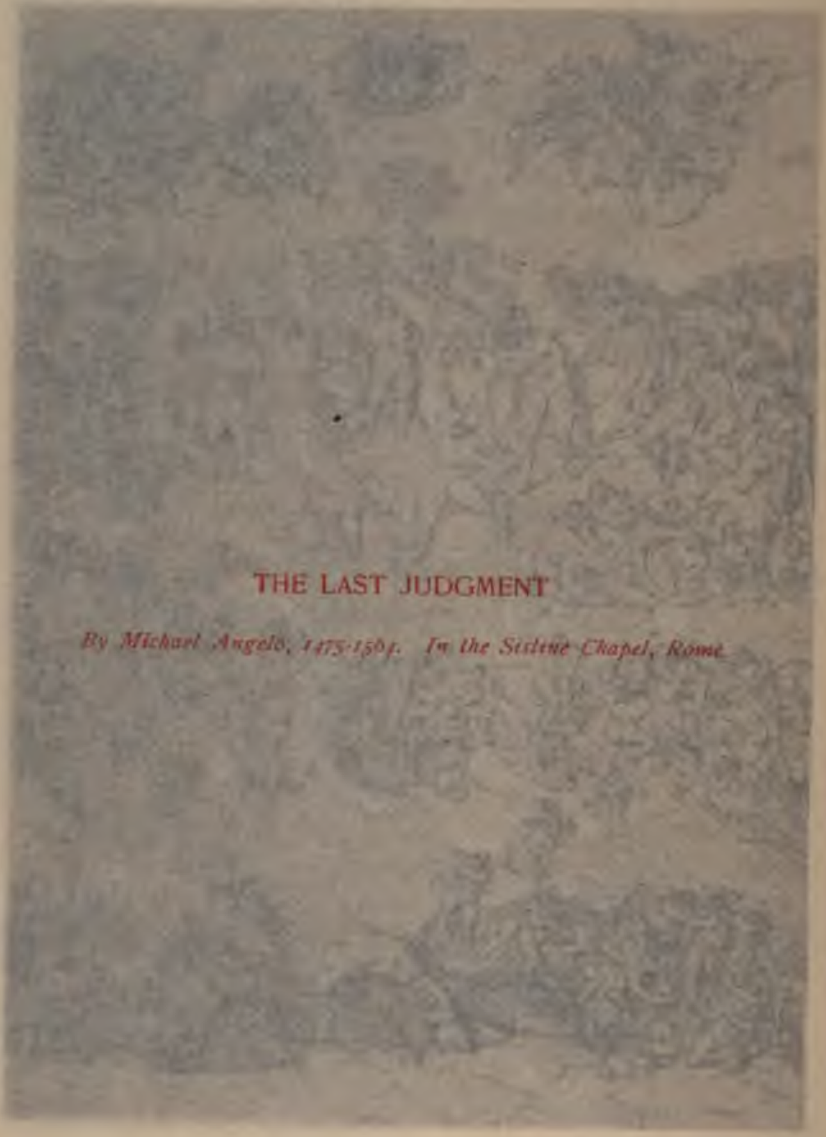
"We took a long glass tube, which, by a dexterous hand and the help of a lamp, was in such a manner crooked at the bottom, that the part turned up was almost parallel to the rest of the tube, and the orifice of this shorter leg of the syphon (if I may so call the whole instrument) being hermetically sealed, the length of it was divided into inches (each of which was subdivided into eight parts) by a straight list of paper, which, containing those divisions, was carefully pasted all along it. Then putting in as much quicksilver as served to fill the arch or bended part of the syphon, that the mercury standing in a level might reach in one leg to the bottom of the divided paper, and just to the same height or horizontal line in the other, we took care, by frequently inclining the tube, so that the air might freely pass from one leg into the other by the sides of the mercury (we took, I say, care), that the air at last included in the shorter cylinder should be of the same laxity with the rest of the air about it. This done, we began to pour quicksilver into the longer leg of the syphon, which, by its weight pressing up that in the shorter leg, did by degrees straighten the included air; and continuing this pouring in of quicksilver till the air in the shorter leg was by condensation reduced to take up but half the space it possessed (I say possessed, not filled) before, we cast our eyes upon the longer leg of the glass, upon which we likewise pasted a slip of paper carefully divided into inches and parts, and we observed, not without delight and satisfaction, that the quicksilver in that longer part of the tube was 29 inches higher than the other. Now that this observation does both very well agree with and confirm our hypothesis, will be easily discerned by him that takes notice what we teach: and Monsieur Pascal and our English friend's [Mr. Townley's] experiments prove, that the greater the weight is that leans upon the air, the more forcible is its endeavor of dilation, and consequently its power of resistance (as other springs are stronger when bent by greater weights). For this being considered, it will appear to agree rarely well with the hypothesis, that as according to it the air in that degree of density, and correspondent measure of resistance, to which the weight of the incumbent atmosphere had brought it, was unable to counterbalance and resist the pressure of a mercurial cylinder of about 29 inches, as we are taught by the Torricellian experiment; so here the same air being brought to a degree of density about twice as great as that it had before, obtains a spring twice as strong as formerly. As may appear by its being able to sustain or resist a cylinder of 29 inches in the longer tube, together with the weight of the atmospherical cylinder that leaned upon those 29 inches of mercury; and, as we just now inferred from the Torricellian experiment, was equivalent to them."

At this stage of the experiments the tube broke, and it was only after several mischances that Boyle was able to complete his observations.

He then proceeded to the converse experiment—that is, to determine the spring of rarefied air. A tube, about 6 feet in length, and sealed at one end, was nearly filled with mercury, and into it was placed "a slender glass pipe of about the bigness of a swan's quill, and open at both ends; all along of which was pasted a narrow list of paper, divided into inches and half-quarters. This slender pipe being thrust down into the greater tube almost filled with quicksilver, the glass helped to make it swell to the top of the tube; and the quicksilver getting in at the lower orifice of the pipe filled it up till the mercury included in that was near about a level with the surface of the surrounding mercury in the tube. There being, as near as we could guess, little more than an inch of the slender pipe left above the surface of the restagnant mercury, and consequently unfilled therewith, the prominent orifice was carefully closed with sealing-wax melted; after which the pipe was let alone for a while that the air, dilated a little by the heat of the wax, might, upon refrigeration, be reduced to its wonted density. And then we observed, by the help of the above-mentioned list of paper, whether we had not included somewhat more or somewhat less than an inch of air; and in either case we were fain to rectify the error by a small hole made (with a heated pin) in the wax, and afterward closed up again. Having thus included a just inch of air, we lifted up the slender pipe by degrees, till the air was dilated to an inch, an inch and a half, two inches, etc., and observed in inches and eighths the length of the mercurial cylinder, which, at each degree of the air's expansion, was impelled above the surface of the restagnant mercury in the tube. The observations being ended, we presently made the Torricellian experiment with the above mentioned great tube of 6 feet long, that we might know the height of the mercurial cylinder for that particular day and hour, which height we found to be 29¾ inches."

Such were the experiments, simple and easily made, which led Boyle to the recognition of the great law which bears his name—a law which is so far from being "unuseful" that it is recognized by the physicist as of the first importance. And yet in spite of the thoroughness with which Boyle did the work, and in spite, too, of the precision with which he stated his results, the attempt has not been wanting to deprive him of the whole merit of this discovery, and there is scarcely a textbook of physics or chemistry on the Continent, or at least in France, in which his name is mentioned in connection with the matter: abroad they prefer to ascribe the glory to the Abbé Mariotte, although Mariotte's treatise, *De la Nature de l'Air,* in which he enunciates the law, was not printed until seventeen years after Boyle had published his reply to Linus.—Thorpe, Essays on Historical Chemistry.





THE LAST JUDGMENT

By Michael Angelo, 1475-1564. In the Sistine Chapel, Rome.

SEVENTEENTH CENTURY POLITICAL ECONOMY

UNTIL the last century political economy—the science of wealth—was discussed hand in hand with political science—the science of government—but for convenience we note elsewhere the growth of governmental ideas. Political economy proper had little consideration in ancient times. The economic decay of the Roman state gave rise to arguments against slave labor and interest on loans, and to measures for the increase of the free population, but economics as a science can hardly be recognized to have existed. All large economic activity ceased during the dark ages, but the subsequent growth of the cities and their trade gave rise to what Adam Smith calls the mercantile theory of economics.

Jean Bodin in the latter half of the sixteenth century made a great step in economic science by explaining the ten-fold rise in prices to the importation of gold from the New World. He distinguished money from wealth, but otherwise was a mercantilist in approving the interference of government in trade, high taxes on manufactured imports, and low taxes on imported raw materials and food. In 1581 W. S. (William Stafford) defended the exclusion of all foreign wares in England. Antonio Serra, an Italian, writing in 1613 in prison, argued in favor of the superior profit to the nation of manufactures and for their protection. Monchrétien de Watteville in 1615 gave an exposition in French of the restrictive ideas. He believed in government control of all industries in the home state and in colonies. Thomas Mun (1571-1641) was the greatest English advocate of this system. He maintained that the great object of governmental economics should be to maintain the balance of trade, that is, the excess of exports over imports, and that trade restrictions and tariffs should be formulated with this end in view. Josiah Child in 1668 and 1690 favored a low rate of interest maintained by government authority and exclusive control of the colonial trade. He believed, like the rest of the mercantilists, in a large and growing population. This, it will be remembered, was in direct opposition to the old Greek idea.

The mercantile theory had been put into practical use by most nations, and everywhere there were fast-bound restrictions on industry. This at length caused a reaction that later led, in what are called the physiocrats, to the opposite extreme.

Sir William Petty (1623-1687) was a precursor of the new school. He founded the value of an article on the labor required to produce it, argued for a single money standard, against a fixed rate of interest, and in general did not believe in government control. Sir Dudley North (1691) was also an opponent of the restrictive theory. He believed in home as well as foreign trade, and in non-interference by the government. John Locke based all property on labor—a theory that implied great political consequences.

These reactionary ideas took root in France and developed rapidly. Pierre Boisguillebert in the first of the eighteenth century, vainly struggled against government restrictions for the sake of manufactures, and lauded agriculture. Restrictions between nations he thought as harmful as between individuals. He brought forward the idea of a tax on incomes. But his words fell on deaf ears and had little influence. Vaubon in 1707 took up the same line of thought and urged more consideration for the laboring and agricultural class.

The great names, however, of the physiocrat school proper belong to the eighteenth century, and were Quesnay (1684-1774) and Gournay (1712-1759). They took for granted the doctrine of the natural rights and equality of man, of the social contract as the basis of the state. They thought that labor is the basis of property, but the soil the source of all wealth. They argued that agriculture, mining, fishing, etc., are the only truly productive occupations; that manufacturies and commerce increase values only by the amount of labor put in them, and that this labor is not really productive because the sum of raw materials is not increased. "Laissez faire," non-intervention, should be the policy of governments. Turgot tried to carry out their ideas in France, but he was unsustained by Louis XVI., and the government plunged on blindly to the Revolution.

In England David Hume brought his keen insight to bear against the balance of trade theory, and the identification of money and wealth. He was a friend of and unquestionably influenced, Adam Smith, but Smith's Wealth of Nations is beyond doubt the beginning of modern political economy.

THOMAS MUN

Thomas Mun was born in London 1571. His father and uncle were both connected with the mint. Mun was early a successful merchant engaged mostly in Turkish trade. In July, 1615, he was elected a director of the East India Company. His first book was a defence of the transactions of that company. His second book, "England's Treasure by Forraign Trade, or the Ballance of our Forraign Trade is the Rule of our Treasure," was probably written about 1630, but not published until 1664, twenty-three years after his death. The book gives the best early expression to the views of the prevailing political economy of the time. It is important, as the influence of the protective theory which it represents has been enormous.

MUN'S "MERCANTILE THEORY"

THE MEANS TO ENRICH THE KINGDOM, AND TO ENCREASE OUR TREASURE

Although a Kingdom may be enriched by gifts received, or by purchase taken from some other nations, yet these are things uncertain and of small consideration when they happen. The ordinary means therefore to encrease our wealth and treasure is by *Forraign Trade*, wherein wee must ever observe this rule: to sell more to strangers yearly than wee consume of theirs in value. For suppose that when this Kingdom is plentifully served with the Cloth, Lead, Tinn, Iron, Fish, and other native commodities, we doe yearly export the overplus to forraign Countries to the value of twenty two hundred thousand pounds; by which means we are enabled beyond the Seas to buy and bring in forraign wares for our use and consumptions, to the value of twenty hundred thousand pounds. By this order duly kept in our trading, we may rest assured that the Kingdom shall be enriched yearly two hundred thousand pounds, which must be brought to us in so much Treasure; because that part of our stock which is not returned to us in wares must necessarily be brought home in treasure.

For in this case it cometh to pass in the stock of a Kingdom, as in the estate of a private man; who is supposed to have one thousand pounds yearly revenue and two thousand pounds of ready money in his Chest: If such a man through excess shall spend one thousand five hundred pounds *per annum*, all his ready money will be doubled if he takes a Frugal course to spend but five hundred pounds *per annum;* which rule never faileth likewise in the Commonwealth, but in some cases (of no great moment) which I will hereafter declare, when I shall shew by whom and in what manner this ballance of the Kingdom's account ought to be drawn up yearly, or so often as it shall please the State to discover how much we gain or lose by trade with forraign Nations. But first I will say something concerning those ways and means which will encrease our exportations and diminish our importations of wares; which being done, I will then set down some other arguments both affirmative and negative to strengthen that which is here declared, and thereby to shew that all the other means which are commonly supposed to enrich the Kingdom with Treasure are altogether insufficient and meer fallacies.

The particular ways and means to encrease the exportation of our Commodities, and to decrease our Consumption of forraign wares.

The revenue or stock of a Kingdom by which it is provided of forraign wares is either *Natural* or *Artificial*. The Natural wealth is so much only as can be spared from our own use and necessities to be exported unto strangers. The Artificial consists in our manufactures and industries trading with forraign commodities, concerning which I will set down such particulars as may serve for the cause we have in hand.

1. First, although this Realm be already exceeding rich by nature, yet might it be much encreased by laying the waste grounds (which are infinite) into such employments as should no way hinder the present revenues of other manured lands, but hereby to supply our selves and

prevent the importations of Hemp, Flax, Cordage, Tobacco, and divers other things which now we fetch from strangers to our great impoverishing.

2. We may likewise diminish our importations if we would soberly refrain from excessive consumption of forraign wares in our diet and rayment, with such often change of fashions as is used, so much the more to encrease the waste and charge; which vices at this present are more notorious amongst us than in former ages. Yet might they easily be amended by enforcing the observation of such good laws as are strictly practised in other Countries against the said excesses; where likewise by commanding their own manufactures to be used, they prevent the coming in of others, without prohibition, or offence to strangers in their mutual commerce.

3. In our exportations we must not only regard our own superfluities, but also we must consider our neighbours' necessities, that so upon the wares which they cannot want, nor yet be furnished thereof elsewhere, we may (besides the vent of the Materials) gain so much of manufacture as we can, and also endeavor to sell them dear, so far forth as the high price cause not a less vent in the quantity. But the superfluity of our commodities which strangers use, and may also have the same from other Nations, or may abate their vent by the use of some like wares from other places, and with little inconvenience; we must in this case strive to sell as cheap as possible we can, rather than to lose the utterance of such wares. For we have found of late years by good experience, that being able to sell our Cloth cheaply in Turkey, we have greatly encreased the vent thereof, and the *Venetians* have lost as much in the utterance of theirs in those Countreys, because it is dearer. And on the other side a few years past, when by the excessive price of Wools our Cloth was exceeding dear, we lost at the least half our clothing for forraign parts, which since is no otherwise (well neer) recovered again than by the great fall of price for Wools and Cloth. We find that twenty five in the Hundred less in the price of these and some other Wares, to the loss of private mens revenues, may raise about fifty upon the hundred in the quantity vented to the benefit of the publique.

For when Cloth is dear, other Nations doe presently practise clothing, and we know they want neither art nor materials to this performance. But when by cheapness we drive them from this employment, and so in time obtain our dear price again, then do they also use their former remedy. So that by these alterations we learn, that it is in vain to expect a greater revenue of our wares than their condition will afford, but rather it concerns us to apply our endeavours to the times with care and diligence to help our selves the best we may, by making our cloth and other manufactures without deceit, which will encrease their estimation and use.

4. The value of our exportations likewise may be much advanced when we perform it ourselves in our own ships, for then we get only not the price of our wares as they are worth here, but also the Merchants gains, the charges of ensurance, and fraight to carry them beyond the Seas. As for example, if the *Italian* Merchants should come hither in their own shipping to fetch our Corn, our red Herrings or the like, in this case the Kingdom should have ordinarily but 25.s for a quarter of Wheat, and 20.s. for a barrel of red herrings, whereas if we carry these wares ourselves into *Italy* upon the same rates, it is likely that we shall obtain fifty shillings for the first, and forty for the last, which is a great difference in the utterance or vent of the Kingdom's stock. And although it is true that the commerce ought to be free to strangers to bring in and carry out at their pleasure, yet nevertheless in many places the exportation of victuals and munition are either prohibited, or at least limited to be done onely by the people and Shipping of those places where they abound.

5. The frugal expending likewise of our own natural wealth might advance much yearly to be exported unto strangers; and if in our rayment we will be prodigal, yet let this be done with our own materials and manufactures, as Cloth, Lace, Imbroderies, Cutworks and the like, where the excess of the rich may be the employment of the poor, whose labours notwithstanding of this kind,would be more profitable for the Commonwealth, if they were done to the use of strangers.

6. The Fishing in his Majesties seas of *England, Scotland* and *Ireland* is our natural wealth, and would cost nothing but labour, which the *Dutch* bestow willingly, and thereby draw yearly a very great profit to themselves by serving many places of Christendom with our Fish, for which they return and supply their wants both of forraign Wares and Mony, besides the multitudes of Mariners and Shipping, which hereby are maintain'd, whereof a long discourse might be made to shew the particular manage of this important business. Our Fishing plantation likewise in *New-England, Virginia, Groenland,* the *Summer Islands,* and the *New-Found-land,* are of the like nature, affording much wealth

and employments to maintain a great number of poor, and to encrease our decaying trade.

7. A staple or Magazin for forraign Corn, Indico, Spices, Raw-silks, Cotton, wool or any other commodity whatsoever, to be imported will encrease Shipping, Trade, Treasure, and the Kings customes, by exporting them again where need shall require, which course of trading, hath been the chief means to raise *Venice, Genoa,* the *low-Countreys,* with some others; and for such a purpose *England* stands most commodiously, wanting nothing to this performance but our own diligence and endeavour.

8. Also wee ought to esteem and cherish those trades which we have in remote or far Countreys, for besides the encrease of Shipping and Mariners thereby, the wares also sent thither and received from thence are far more profitable unto the kingdom than by our trades neer at hand: As for example: suppose Pepper to be worth here two Shillings the pound constantly, if then it be brought from the *Dutch* at *Amsterdam,* the Merchant may give there twenty pence the pound, and gain well by the bargain, but if he fetch this Pepper from the East-Indies, he must not give above three pence the pound at the most, which is a mighty advantage, not only in that part which serveth for our own use, but also for that great quantity which (from hence) we transport yearly unto divers other Nations to be sold at a higher price: whereby it is plain, that we make a far greater stock by gain upon these *Indian* Commodities, than those Nations doe where they grow, and to whom they properly appertain, being the natural wealth of their Countries. But for the better understanding of this particular, we must ever distinguish between the gain of the Kingdom, and the profit of the Merchant; for although the Kingdom payeth no more for this Pepper than is before supposed, nor for any other commodity bought in forraign parts more than the stranger receiveth from us for the same, yet the merchant payeth not only that price, but also the fraight, ensurance, customes and other charges which are exceeding great in these long voyages, but yet all these in the Kingdoms accompt are but commutations among our selves, and no privation of the Kingdom stock, which being duly considered, together with the support also of our other trades in our best Shipping to *Italy, France, Turkey,* the *East Countreys* and other places, by transporting and venting the wares which we bring yearly from the *East Indies;* It may well stir up our utmost endeavours to maintain and enlarge this great and noble business, so much importing the Publique

wealth, Strength, and Happiness. Neither is there less honour and judgment by growing rich (in this manner) upon the stock of other Nations, than by an industrious encrease of our own means, especially when this later is advanced by the benefit of the former, as we have found in the *East Indies* by sale of much of our Tin, Cloth, Lead and other Commodities, the vent thereof doth daily encrease in those Countreys which formerly had no use of our wares.

9. It would be very beneficial to export money as well as wares, being done in trade only, it would encrease our Treasure; but of this I write more largely in the next Chapter to prove it plainly.

10. It were policie and profit for the State to suffer manufactures made of forraign Materials to be exposed custome-free, as Velvets and all other wrought Silks, Fustians, thrown Silks and the like, it would employ very many poor people, and much encrease the value of our stock yearly issued into other Countreys, and it would (for this purpose) cause the more forraign Materials to be brought in, to the improvement of His Majesties Customes. I will here remember a notable increase in our manufacture of winding and twisting only of forraign raw Silk, which within 35 years to my knowledge did not employ more than 300. people in the City and suburbs of London, where at this present time it doth set on work above fourteen thousand souls, as upon diligent enquiry hath been credibly reported unto His Majesties Commissioners for Trade. And it is certain, that if the said forraign Commodities might be exported from hence, free of customes, this manufacture would yet encrease very much, and decrease as fast in *Italy* and the *Netherlands.* But if any man allege the *Dutch* proverb, *Live and let others live,* I answer, that the Dutchmen notwithstanding their own proverb, doe not onely in these Kingdoms, encroach upon our livings, but also in other forraign parts of our trade (where they have power) they do hinder and destroy us in our lawful course of living, hereby taking the bread out of our mouth, which we shall never prevent by plucking the pot from their nose, as of late years too many of us do practise to the great hurt and dishonour of this famous Nation. We ought rather to imitate former times in taking sober and worthy courses more pleasing to God and suitable to our ancient reputation.

11. It is needful also not to charge the native commodities with too great customes, lest by indearing them to the strangers use, it hinder their vent. And especially forraign wares brought in to be transported again should be favoured, for otherwise that manner of trading (so

much importing the good of the Common wealth) cannot prosper nor subsist. But the Consumption of such forraign wares in the Realm may be the more charged, which will turn to the profit of the Kingdom in the *Ballance of the Trade,* and thereby also enable the King to lay up the more Treasure out of his yearly incomes, as of this particular I intend to write more fully in its proper place, where I shall shew how much money a Prince may conveniently lay up without the hurt of his subjects.

12. Lastly, in all things we must endeavour to make the most we can of our own, whether it be Natural or Artificial; And forasmuch as the people which live by the arts are far more in number than those who are masters of the fruits, we ought the more carefully to maintain those endeavours of the multitude, in whom doth consist the greatest strength and riches of King and Kingdom: for where the people are many, and the arts good, there the traffique must be great, and the Countrey rich. The *Italians* employ a greater number of people, and get more money by their industry and manufactures of the raw Silks of the Kingdom of *Cicilia,* than the King of *Spain* and his subjects have by the revenue of this rich commodity. But what need we fetch the example so far, when we know that our own natural wares do not yield so much profit as our industry? For Iron oar in the Mines is of no great worth, when it is compared with the employment and advantage it yields being digged, tried, transported, bought, sold, cast into Ordnance, Muskets, and many other instruments of war for offence and defence, wrought into Anchors, bolts, spikes, nayles and the like, for the use of Ships, Houses, Carts, Coaches, Ploughs, and other instruments for Tillage. Compare our Fleece-wools with our Cloth, which requires shearing, washing, carding, spinning, Weaving, fulling, dying, dressing and other trimmings, and we shall find these Arts more profitable than the natural wealth, whereof I might instance other examples, but I will not be more tedious, for if I would amplify upon this and the other particulars before written, I might find matter sufficient to make a large volume, but my desire in all is only to prove what I propound with brevity and plainness.—Reprint from first edition.

JOHN LOCKE

THE BASIS OF PROPERTY IS LABOR

WHETHER we consider natural reason, which tells us that men, being once born, have a right to their preservation, and consequently to meat and drink, and such other things as nature affords for their subsistence; or revelation, which gives us an account of those grants God made of the world to Adam, and to Noah, and to his sons, it is very clear that God, as King David says, Psl. cxv. 16, "has given the earth to the children of men;" given to mankind in common. But this being supposed, it seems to some a very great difficulty, how any one should ever come to have a property in any thing. I will not content myself to answer, that if it be difficult to make out property upon a supposition, that God gave the world to Adam, and his posterity in common, it is impossible that any man, but one universal monarch, should have any property upon a supposition that God gave the world to Adam, and his heirs in succession, exclusive of all the rest of his posterity. But I shall endeavor to shew, how men might come to have a property in several parts of that which God gave to mankind in common, and that without any express compact of all the commoners.

God, who hath given the world to men in common, hath also given them reason to make use of it to the best advantage of life, and convenience. The earth, and all that is therein, is given to men for the support and comfort of their being. And though all the fruits it naturally produces, and beasts it feeds, belonged to mankind in common, as they are produced by the spontaneous hand of nature; and nobody has originally a private dominion, exclusive of the rest of mankind, in any of them, as they are thus in their natural state: yet being given for the use of men, there must of necessity be a means to appropriate them some way or other, before they can be of any use, or at all beneficial to any particular man. The fruit, or venison, which nourishes the wild Indian, who knows no inclosure, and is still a tenant in common, must be his, and so his, i. e., a part of him, that another can no longer have any right to it, before it can do him any good for the support of life.

Though the earth, and all inferior creatures, be common to all men, yet every man has a property in his own person: this no body has any right to but himself. The labour of his body, and the work of his hands, we may say, are properly his. Whatsoever then he removes of the state nature has provided, and left it in, he hath mixed his labours with, and joined to it something that is his own, and thereby makes it his property. It being by him removed from the common state nature hath placed it in, it hath by this labour something annexed to it, that excludes the common right of other men. For this labour being the unquestionable property of the labourer, no man but he can have a right to what is once joined to, at least where there is enough, and as good, left in common for others.

He that is nourished by the acorns he picks upon an oak, or the apples he gathers from the trees in the wood, has certainly appropriated them to himself. No body can deny but the nourishment is his. I ask then, when did they begin to be his? when he digested? or when he eats? or when he boiled? or when he brought them home? or when he picked them up? and it is plain, if the first gathering made them not his, nothing else could. That labour put a distinction between them and the common: that added something to them more than nature, the common mother of all, had done; and so they became his private right. And will anyone say, he had no right to those acorns or apples he thus appropriated, because he had not the consent of all mankind to make them his? Was it a robbery thus to assume to himself what belonged to all in common? If such a consent as that was necessary, man had starved, notwithstanding the plenty God had given him. We see in commons, which remain so by compact, that it is the taking any part of what is common, and removing it out of the state nature leaves it in, which begins the property: without which the common is of no use. And the taking of this or that part, does not depend on the express consent of all the commoners. Thus the grass my horse has bit: the turfs my servant has cut; and the ore I have digged in my place, where I have a right to them in common with others, become my property, without the assignation or consent of any body. The labour that was mine, removing them out of that common state they were in, hath fixed my property in them.

By making an explicit consent of every commoner necessary in any one's appropriation to himself any part of what is given in common;

children or servants could not cut the meat, which their father or master had provided for them in common, without assigning to every one his peculiar part. Though the water running in the fountain be every one's, yet who can doubt, but that in the pitcher is his only who drew it out? His labour hath taken it out of the hands of nature, where it was common, and belonged equally to all her children, and hath thereby appropriated it to himself.

Thus this law of reason makes the deer that Indian's who hath killed it; it is allowed to be his goods, who has bestowed his labour upon it, though before it was the common right of everyone. And amongst those who are counted the civilized part of mankind, who have made and multiplied positive laws to determine property, this original law of nature, for the beginning of property, in what was before common, still takes place; and by virtue thereof, what fish any one catches in the ocean, and great and still remaining common of mankind; or what ambergrise any one takes up here, is by the labour that removes it out of that common state nature left it in, made his property, who takes that pains about it. And even amongst us, the hare that any one is hunting, is thought his who pursues her during the chase: for being a beast that is still looked upon as common, and no man's private possession; whosoever has employed so much labour about any of that kind, as to find and pursue her, has thereby removed her from the state of nature, wherein she was common, and hath begun a property.

It will perhaps be objected to this, that " if gathering the acorns, or other fruits of the earth, &c. makes a right to them, then can anyone ingross as much as he will." To which I answer, Not so. The same law of nature, that does by this means give us property, does also bound that property too. "God has given us all things richly," 1 Tim. vi. 12, is the voice of reason confirmed by inspiration. But how far has he given it to us? To enjoy. As much as anyone can make use of to any advantage of life before it spoils, so much be may by his labour fix a property in: whatever is beyond this, is more than his share, and belongs to others. Nothing was made by God for man to spoil or destroy. And thus, considering the plenty of natural provisions there was a long time in the world, and a few spenders; and to how small a part of that provision the industry of any man could extend itself, and ingross it to the prejudice of others; especially keeping within the bounds, set by reason, of what might serve for his use; there could then be little room for quarrels or contentions about property so established.

But the chief matter of property being now not the fruits of the earth, and the beasts that subsist on it, but the earth itself; as that which takes in and carries with it all the rest; I think it is plain, that property in that too is acquired as the former. As much land as a man tills, plants, improves, cultivates, and can use the product of, so much is his property. He by his labour does, as it were, inclose it from the common. Nor will it invalidate his right, to say everybody else has an equal title to it; and therefore he cannot appropriate, he cannot inclose, without the consent of all his fellow commoners, all mankind. God, when he gave the world in common to all mankind, commanded man also to labour, and the penury of his condition required it of him. God and his reason commanded him to subdue the earth, i. e. improve it for the benefit of life, and therein lay out something upon it that was his own, his labour. He that in obedience to this command of God subdued, tilled and sowed any part of it, thereby annexed to it something that was his property, which another had no title to, nor could without injury take it from him.

Nor was this appropriation of any parcel of land, by improving it, any prejudice to any other man, since there was still enough, and as good left; and more than the yet unprovided could use. So that, in effect, there was never the less left for others because of his inclosure for himself: for he that leaves as much as another can make use of, does as good as take nothing at all. No body could think himself injured by the drinking of another man, though he took a good draught, who had a whole river of the same water left him to quench his thirst; and the case of land and water, where there is enough of both, is perfectly the same.

God gave the world to men in common: but since he gave it to them for their benefit, and the greatest conveniencies of life they were capable to draw from it, it cannot be supposed he meant it should always remain common and uncultivated. He gave to the use of the industrious and rational (and labour was to be his title to it); not to the fancy or covetousness of the quarrelsome and contentious. He that had as good left for his improvement as was already taken up, needed not to complain, ought not to meddle with what was already improved by another's labour: if he did, it is plain he desired the benefit of another's pains, which he had no right to, and not the ground which God had given him in common with others to labour on, and whereof there was as good left, as that already possessed, and more than he knew what to do with, or his industry could reach to.

It is true, in land that is common in England, or any other country, where there is plenty of people under government, who have money and commerce, no one can inclose or appropriate any part, without the consent of all his fellow-commoners; because this is left common by compact, i. e. by the law of the land, which is not to be violated. And though it be common, in respect to some men, it is not so to all mankind; but is the joint property of this country, or this parish. Besides, the remainder, after such inclosure, would not be as good to the rest of the commoners, as the whole was when they could all make use of the whole; whereas in the beginning and first peopling of the great common of the world, it was quite otherwise. The law man was under, was rather for appropriating. God commanded, and his wants forced him to labour. That was his property which could not be taken from him wherever he had fixed it. And hence subduing or cultivating the earth, and having dominion, we see are joined together. The one gave title to the other. So that God, by commanding to subdue, gave authority so far to appropriate; and the condition of human life, which requires labour and materials to work on, necessarily introduces private possessions.

The measure of property nature has well set by the extent of men's labour, and the conveniences of life: no man's labour could subdue, or appropriate all; nor could his enjoyment consume more than a small part; so that it was impossible for any man, this way, to intrench upon the right of another, or acquire to himself a property, to the prejudice of his neighbour, who would still have room for as good and as large a possession (after the other had taken out his) as before it was appropriated. This measure did confine every man's possession to a very moderate proportion, and such as he might appropriate to himself, without injury to any body, in the first ages of the world, when men were in more danger to be lost, by wandering from their company, in the then vast wilderness of the earth, than to be straitened for want of room to plant in. And the same measure may be allowed still without prejudice to any body, as full as the world seems: for supposing a man, or family, in the state they were at first peopling of the world by the children of Adam, or Noah; let him plant in some inland, vacant places of America, we shall find that the possessions he could make himself, upon the measures we have given, would not be very large, nor, even to this day, prejudice the rest of mankind, or give them reason to complain or think themselves injured by this man's incroachment; though the race of men have now spread themselves to all the corners of the world, and do infinitely exceed the small number at the beginning. Nay, the extent of ground is of so little value, without labour, that I have heard it affirmed, that in Spain itself a man may be permitted to plough, sow and reap, without being disturbed, upon land he has no other title to, but only his making use of it. But, on the contrary, the inhabitants think themselves beholden to him, who, by his industry on neglected, and consequently waste land, has increased the stock of corn, which they wanted. But be this as it will, which I lay no stress on; this I dare boldly affirm, that the same rule of propriety, (viz.) that every man should have as much as he could make use of, would hold still in the world, without straitening any body; since there is land enough in the world to suffice double the inhabitants, had not the invention of money, and the tacit of men to put a value on it, introduced (by consent) larger possessions, and a right to them; which, how it has done, I shall by and by shew more at large.

This is certain, that in the beginning, before the desire of having more than man needed, had altered the intrinsic value of things, which depends only on their usefulness to the life of man; or had agreed, that a little piece of yellow metal, which would keep without wasting or decay, should be worth a great piece of flesh, or a whole heap of corn; though men had a right to appropriate, by their labour, each one to himself, as much of the things of nature, as he could use: yet this could not be much, nor to the prejudice of others, where the same plenty was still left to those who would use the same industry. To which let me add, that he who appropriates land to himself by his labour, does not lessen, but increase the common stock of mankind: for the provisions serving to the support of human life, produced by one acre of inclosed and cultivated land, are (to speak much within compass) ten times more than those which are yielded by one acre of land of an equal richness lying waste in common. And therefore he that incloses land, and has a greater plenty of the conveniences of life from ten acres, than he could have from an hundred left to nature, may truly be said to give ninety acres to mankind: for his labour now supplies him with provisions out of ten acres, which were but the product of an hundred lying in common. I have here rated the improved land very low, in making its product but as ten to one, when it is much nearer an hundred to one: for I ask, whether in the wild woods and uncultivated waste of America, left to nature, without any improvement, tillage or husbandry, a thousand acres yield the needy and wretched inhabitants as many conveniences of life, as ten acres of equally fertile land do in Devonshire, where they are well cultivated.

Before the appropriation of land, he who gathered as much of the wild fruit, killed, caught, or tamed, as many of the beasts, as he could; he that so employed his pains about any of the spontaneous products of nature, as any way to alter them from the state which nature put them in, by placing any of his labour on them, did thereby acquire a property in them; but if they perished, in his possession, without their due use; if the fruits rotted, or the venison putrified, before he could spend it, he offended against the common law of nature, and was liable to be punished; he invaded his neighbour's share, for he had no right, farther than his use called for any of them, and they might serve to afford his conveniences of life.

The same measures governed the possession of land too: whatsoever he tilled and reaped, laid up and made use of, before it spoiled, that was his peculiar right; whatsoever he enclosed, and could feed, and make use of, the cattle and product was also his. But if either the grass of his inclosure rotted on the ground, or the fruit of his planting perished without gathering, and laying up; this part of the earth, notwithstanding his inclosure, was still to be looked on as waste, and might be the possession of any other. Thus, at the beginning, Cain might take as much ground as he could till, and make it his own land, and yet leave enough to Abel's sheep to feed on: a few acres would serve for their possessions. But as families increased, and industry enlarged their stocks, their possessions enlarged with the need of them; but yet it was commonly without any fixed property in the ground they made use of, till they incorporated, settled themselves together, and built cities; and then, by consent, they came in time, to set out the bounds of their distinct territories, and agree on limits between them and their neighbors; and by laws within themselves, settled the properties of those of the same society: for we see, that in that part of the world which was first inhabited, and therefore like to be best peopled, even as low down as Abraham's time, they wandered with their flocks and their herds, which was their substance, freely up and down; and this Abraham did in a country where he was a stranger. Whence it is plain, that at least a great part of the land lay in common; that the inhabitants valued it not, nor claimed property in any more than they made use of. But when there was not room enough in the same place, for their herds to feed together, they by consent, as Abraham and Lot did, Gen. xiii. 5, separated and enlarged their pasture, where it best liked them. And for the same reason Esau went from his father, and his brother, and planted in Mount Seir, Gen. xxxvi. 6.

And thus, without supposing any private dominion, and property in Adam, over all the world, exclusive of all other men, which can no way be proved, nor any one's property be made out from it; but supposing the world given, as it were, to the children of men in common, we see how labour could make men distinct titles to several parcels of it, for their private uses; wherein there could be no doubt of right, no room for quarrel.

EIGHTEENTH CENTURY PHILOSOPHY

BERKELEY

Our introduction to modern philosophy in this volume is a sufficient preface to the philosophy of the eighteenth century.

Berkeley was born at Kilkenny, Ireland, in March, 1685. He entered Trinity College, Dublin, in 1700, and remained there for the next thirteen years.

Locke and Descartes were the best known philosophers at that time and Berkeley was much interested in both. In 1709 he published his Essay towards a New Theory of Vision. In this he argued that all that is actually given us by sight is a color sensation—not distance, nor even space dimensions. In 1710 he published his Principles of Human Knowledge. Locke had declared that we get all our knowledge from sensations and our reflections upon them—that we can have no definite idea of substances, but must suppose them in order to have something to support the qualities given us in sensation. Berkeley went farther than this. He argues that the only things we know are mental and the only cause of things we know is our own will, which, too, is mental, and concludes that we have no right to suppose this unknown substance to be anything but mental, that is, God. Later he further explained his thought in his dialogues, considering the world of our sensations as in a way the symbolic language of God. In 1713 he visited London, and some years later Italy. In 1724 he was made Dean of Derry. He planned a college in the Bermudas, and spent three years in Rhode

Island. Most of the rest of his life was spent in southern Ireland as Bishop of Cloyne. He died at Oxford in January, 1753.

PRINCIPLES OF HUMAN KNOWLEDGE

1. IT IS evident to any one who takes a survey of the objects of human knowledge that they are either *ideas* actually imprinted on the senses; or else such as are perceived by attending to the passions and operations of the mind; or lastly *ideas* formed by help of memory and imagination—either compounding, dividing, or barely representing those originally perceived in the aforesaid ways.—By sight I have the ideas of light and colours, with their several degrees and variations. By touch I perceive hard and soft, heat and cold, motion and resistance, and of all these more and less either as to quantity or degree. Smelling furnishes me with odours; the palate with tastes; and hearing conveys sounds to the mind in all their variety of tone and composition.—And as several of these are observed to accompany each other, they come to be marked by one name, and so to be reputed as one THING. Thus, for example, a certain colour, taste, smell, figure and consistence having been observed to go together, are accounted one distinct thing, signified by the name *apple;* other collections of ideas constitute a stone, a tree, a book, and the like sensible things—which as they are pleasing or disagreeable excite the passions of love, hatred, joy, grief, and so forth.

2. But, besides all that endless variety of ideas or objects of knowledge, there is likewise something which knows or perceives them; and exercises divers operations, as willing, imagining, remembering, about them. This perceiving, active being is what I call MIND, SPIRIT, SOUL, or MYSELF. By which words I do not denote any one of my ideas, but a thing entirely distinct from them, wherein they exist, or, which is the same thing, whereby they are perceived—for the existence of an idea consists in being perceived.

3. That neither our thoughts, nor passions, nor ideas formed by the imagination, exist without the mind, is what everybody will allow.—And to me it is no less evident that the various SENSATIONS, or *ideas imprinted on the sense,* however blended or combined together (that is, whatever *objects* they compose), cannot exist otherwise than in a mind perceiving them—I think an intuitive knowledge may be obtained of this by any one that shall attend to *what is meant by the term exist when*

applied to sensible things. The table I write on I say exists, that is, I see and feel it; and if I were out of my study I should say it existed—meaning thereby that if I was in my study I might perceive it, or that some other spirit actually does perceive it. There was an odour, that is, it was smelt; there was a sound, that is, it was heard; a colour or figure, and it was perceived by sight or touch. This is all that I can understand by these and the like expressions.—For as to what is said of the absolute existence of unthinking things without any relation to their being perceived, that is to me perfectly unintelligible. Their *esse* is *percipi,* nor is it possible they should have any existence out of the minds or thinking things which perceive them.

4. It is indeed an opinion strangely prevailing amongst men, that houses, mountains, rivers, and in a word all sensible objects, have an existence, natural or real, distinct from their being perceived by the understanding. But, with how great an assurance and acquiescence soever this principle may be entertained in the world, yet whoever shall find in his heart to call it in question may, if I mistake not, perceive it to involve a manifest contradiction. For, what are the forementioned objects but the things we perceive by sense? and what do we perceive besides our own ideas or sensations? and is it not plainly repugnant that any one of *these,* or any combination of them, should exist unperceived?

5. If we thoroughly examine this tenet it will, perhaps, be found at bottom to depend on the doctrine of *abstract ideas.* For can there be a nicer strain of abstraction than to distinguish the *existence* of sensible objects from their *being perceived,* so as to conceive them existing unperceived? Light and colours, heat and cold, extension and figures—in a word the things we see and feel—what are they but so many sensations, notions, ideas, or impressions on the sense, and is it possible to separate, even in thought, any of these from perception? For my part, I might as easily divide a thing from itself. I may, indeed, divide in my thoughts, or conceive apart from each other, those things which, perhaps, I never perceived by sense so divided. Thus, I imagine the trunk of a human body without the limbs, or conceive the smell of a rose without thinking on the rose itself. So far, I will not deny, I can abstract— if that may properly be called *abstraction* which extends only to the conceiving separately such objects as it is possible may really exist or be actually perceived asunder. But my conceiving or imagining power does not extend beyond the possibility of real existence or perception. Hence, as it is impossible for me to see or feel anything without

an actual sensation of that thing, so it is impossible for me to conceive in my thoughts any sensible thing or object distinct from the sensation or perception of it. [In truth, the object and the sensation are the same thing and cannot therefore be abstracted from each other.]

6. Some truths there are so near and obvious to the mind that a man need only open his eyes to see them. Such I take this important one to be, viz., that all the choir of heaven and furniture of the earth, in a word all those bodies which compose the mighty frame of the world, have not any subsistence without a mind—that their *being* is *to be perceived or known;* that consequently so long as they are not actually perceived by me, or do not exist in my mind or that of any other created spirit, they must either have no existence at all, or else subsist in the mind of some Eternal Spirit—it being perfectly unintelligible, and involving all the absurdity of abstraction, to attribute to any single part of them an existence independent of a spirit. To be convinced of which, the reader need only reflect, and try to separate in his own thoughts the *being* of a sensible thing from its *being perceived.*

7. From what has been said it is evident there is not any other Substance than SPIRIT, or *that which perceives.* But, for the fuller demonstration of this point, let it be considered the sensible qualities are colour, figure, motion, smell, taste, &c., *i. e.,* the ideas perceived by sense. Now, for an idea to exist in an unperceiving thing is a manifest contradiction; for to have an idea is all one as to perceive; that therefore wherein colour, figure, &c. exist must perceive them; hence it is clear there can be no unthinking substance or *substratum* of those ideas.

8. But, say you, though the ideas themselves do not exist without the mind, yet there may be things like them, whereof they are copies or resemblances, which things exist without the mind in an unthinking substance. I answer, an idea can be like nothing but an idea; a colour or figure can be like nothing but another colour or figure. If we look but never so little into our thoughts, we shall find it impossible for us to perceive a likeness except only between our ideas. Again, I ask whether those supposed originals or external things, of which our ideas are the pictures or representations, be themselves perceivable or no? If they are, then they are ideas and we have gained our point; but if you say they are not, I appeal to any one whether it be sense to assert a colour is like something which is invisible; hard or soft, like something which is intangible; and so of the rest.

9. Some there are who make a distinction betwixt *primary* and

secondary qualities. By the former they mean extension, figure, motion, rest, solidity, impenetrability, and number; by the latter they denote all other sensible qualities, as colours, sounds, tastes, and so forth. The ideas we have of these last they acknowledge not to be the resemblances of anything existing without the mind, or unperceived, but they will have our ideas of the primary qualities to be patterns or images of things which exist without the mind, in an unthinking substance which they call Matter.—By Matter, therefore, we are to understand *an inert, senseless substance, in which extension, figure and motion do actually subsist.* But it is evident, from what we have already shewn, that extension, figure, and motion are only ideas existing in the mind, and that an idea can be like nothing but another idea, and that consequently neither they nor their archetypes can exist in an unperceiving substance. Hence, it is plain that the very notion of what is called *Matter* or *corporeal substance* involves a contradiction in it.

10. They who assert that figure, motion, and the rest of the primary or original qualities do exist without the mind, in unthinking substances, do at the same time acknowledge that colours, sounds, heat, cold, and suchlike secondary qualities, do not—which they tell us are sensations existing in the mind alone, that depend on and are occasioned by the different size, texture, and motion of the minute particles of matter. This they take for an undoubted truth, which they can demonstrate beyond all exception. Now, if it be certain that those original qualities are inseparably united with the other sensible qualities, and not, even in thought, capable of being abstracted from them, it plainly follows that they exist only in the mind. But I desire any one to reflect and try whether he can, by any abstraction of thought, conceive the extension and motion of a body without all other sensible qualities. For my own part, I see evidently that it is not in my power to frame an idea of a body extended and moving, but I must withal give it some colour or other sensible quality which is acknowledged to exist only in the mind. In short, extension, figure, and motion, abstracted from all other qualities, are inconceivable. Where therefore the other sensible qualities are, there must these be also, to wit, in the mind and nowhere else.

11. Again, *great* and *small, swift* and *slow,* are allowed to exist nowhere without the mind, being entirely relative, and changing as the frame of position of the organs of sense varies. The extension therefore which exists without the mind is neither great nor small, the

motion neither swift nor slow, that is, they are nothing at all. But, say you, they are extension in general, and motion in general: thus we see how much the tenet of extended moveable substances existing without the mind depends on that strange doctrine of *abstract* ideas. And here I cannot but remark how nearly the vague and indeterminate description of Matter or corporeal substance, which the modern philosophers are run into by their own principles, resembles that antiquated and so much ridiculed notion of *materia prima,* to be met with in Aristotle and his followers. Without extension solidity cannot be conceived; since therefore it has been shewn that extension exists not in an unthinking substance, the same must also be true of solidity.

12. That number is entirely the creature of the mind, even though the other qualities be allowed to exist without, will be evident to whoever considers that the same thing bears a different denomination of number as the mind views it with different respects. Thus, the same extension is one, or three, or thirty-six, according as the mind considers it with reference to a yard, a foot, or an inch. Number is so visibly relative and dependent on men's understanding, that it is strange to think how any one should give it an absolute existence without the mind. We say one book, one page, one line, etc.; all these are equally units, though some contain several of the others. And in each instance, it is plain, the unit relates to some particular combination of ideas arbitrarily put together by the mind.

13. Unity I know some will have to be a simple or uncompounded idea, accompanying all other ideas into the mind. That I have any such idea answering the word *unity* I do not find; and if I had, methinks I could not miss finding it: on the contrary, it should be the most familiar to my understanding, since it is said to accompany all other ideas, and to be perceived by all the ways of sensation and reflexion. To say no more, it is an *abstract* idea.

14. I shall further add, that, after the same manner as modern philosophers prove certain sensible qualities to have no existence in Matter, or without the mind, the same thing may be likewise proved of all other sensible qualities whatsoever. Thus, for instance, it is said that heat and cold are affections only of the mind, and not at all patterns of real beings existing in the corporeal substances which excite them, for that the same body which appears cold to one hand seems warm to another. Now, why may we not as well argue that figure and extension are not patterns or resemblances of qualities existing in Mat-

ter, because to the same eye at different stations, or eyes of a different texture at the same station, they appear various, and cannot therefore be the images of anything settled and determinate without the mind? Again, it is proved that sweetness is not really in the sapid thing, because the thing remaining unaltered the sweetness is changed into bitter, as in case of a fever or otherwise vitiated palate. Is it not as reasonable to say that motion is not without the mind, since if the succession of ideas in the mind become swifter the motion, it is acknowledged, shall appear slower without any alteration in any external object.

15. In short, let any one consider those arguments which are thought manifestly to prove that colours and tastes exist *only* in the mind, and he shall find they may with equal force be brought to prove the same thing of extension, figure, and motion.—Though it must be confessed this method of arguing does not so much prove that there is no extension or colour in an outward object, as that *we* do not know by *sense* which is the *true* extension or colour of the object. But the arguments foregoing plainly shew it to be impossible that any colour or extension at all, or other sensible quality whatsoever, should exist in an unthinking subject without the mind, or in truth, that there should be any such thing as an outward object.

16. But let us examine a little the received opinion.—It is said extension is a mode or accident of Matter, and that Matter is the *substratum* that supports it. Now I desire that you would explain to me what is meant by Matter's *supporting* extension. Say you, I have no idea of Matter and therefore cannot explain it. I answer, though you have no posititve, yet, if you have any meaning at all, you must at least have a relative idea of Matter; though you know not what it is, yet you must be supposed to know what relation it bears to accidents, and what is meant by its supporting them. It is evident "support" cannot here be taken in its usual or literal sense—as when we say that pillars support a building; in what sense therefore must it be taken?

17. If we inquire into what the most accurate philosophers declare themselves to mean by *material substance,* we shall find them acknowledge they have no other meaning annexed to those sounds but the idea of *being in general,* together with the relative notion of its *supporting accidents.* The general idea of Being appeareth to me the most abstract and incomprehensible of all other; and as for its supporting accidents, this, as we have just now observed, cannot be understood in the common sense of those words; it must therefore be taken in some

other sense, but what that is they do not explain. So that when I consider the two parts or branches which make the signification of the words *material substance,* I am convinced there is no distinct meaning annexed to them. But why should we trouble ourselves any farther, in discussing this material *substratum* or "support" of figure, and motion, and other sensible qualities? Does it not suppose *they* have an existence without the mind? And is not this a direct repugnancy, and altogether inconceivable?

18. But, though it were possible that solid, figured, moveable *substances* may exist without the mind, corresponding to the ideas we have of bodies, yet how is it possible for us to know this? Either we must know it by Sense or by Reason.—As for our senses, by them we have the knowledge only of our sensations, ideas, or those things that are immediately perceived by sense, call them what you will: but they do not inform us that things exist without the mind, or unperceived, like to those which are perceived. This the Materialists themselves acknowledge.—It remains therefore that if we have any knowledge at all of external things, it must be by Reason inferring their existence from what is immediately perceived by sense. But what reason can induce us to believe the existence of bodies without the mind, from what we perceive, since the very patrons of Matter themselves do not pretend there is any *necessary* connexion betwixt them and our ideas? I say it is granted on all hands—and what happens in dreams, frenzies, and the like, puts it beyond dispute—that it is possible we might be affected with all the ideas we have now, though there were no bodies existing without resembling them. Hence, it is evident the supposition of external bodies is not necessary for the producing our ideas; since it is granted they are produced sometimes, and might possibly be produced always in the same order we see them in at present, without their concurrence.

19. But, though we might possibly have all our sensations without them, yet perhaps it may be thought easier to conceive and explain the manner of their production, by supposing eternal bodies in their likeness rather than otherwise; and so it might be at least probable there are such things as bodies that excite their ideas in our minds. But neither can this be said; for, though we give the Materialists their external bodies, they by their own confession are never the nearer knowing *how* our ideas are produced; since they own themselves unable to comprehend in what manner body can act upon spirit, or how it is possi-

ble it should imprint any idea in the mind. Hence it is evident the production of ideas or sensations in our minds can be no reason why we should suppose Matter or corporeal substances, since *that* is acknowledged to remain equally inexplicible with or without this supposition. If therefore it were possible for bodies to exist without the mind, yet to hold they do so must needs be a very precarious opinion; since it is to suppose, without any reason at all, that God has created innumerable beings that are entirely useless, and serve to no manner of purpose.

20. In short, if there were external bodies, it is impossible we should ever come to know it; and if there were not, we might have the very same reasons to think there were that we have now. Suppose—what no one can deny possible—an intelligence *without the help of external bodies,* to be affected with the same train of sensations or ideas that you are, imprinted in the same order and with like vividness in his mind. I ask whether that intelligence hath not all the reason to believe the existence of corporeal substances, represented by his ideas, and exciting them in his mind, that you can possibly have for believing the same thing? Of this there can be no question—which one consideration were enough to make any reasonable person suspect the strength of whatever arguments he may think himself to have, for the existence of bodies without the mind.

21. Were it necessary to add any farther proof against the Existence of Matter, after what has been said, I could instance several of those errors and difficulties (not to mention impieties) which have sprung from that tenet. It has occasioned numberless controversies and disputes in philosophy, and not a few of far greater moment in religion. But I shall not enter into the detail of them in this place, as well because I think arguments *a posteriori* are unnecessary for confirming what has been, if I mistake not, sufficiently demonstrated *a priori,* as because I shall hereafter find occasion to speak somewhat of them.

22. I am afraid I have given cause to think I am needlessly prolix in handling this subject. For, to what purpose is it to dilate on that which may be demonstrated with the utmost evidence in a line or two, to any one that is capable of the least reflection? It is but looking into your own thoughts, and so trying whether you can conceive it possible for a sound, or figure, or motion, or colour to exist without the mind or unperceived. This easy trial may perhaps make you see that what you contend for is a downright contradiction. Insomuch that I am content to put the whole upon this issue:—If you can but conceive it possible

for one extended moveable substance, or, in general, for any one idea, or anything like an idea, to exist otherwise than in a mind perceiving it, I shall readily give up the cause. And, as for all that compages of external bodies you contend for, I shall grant you its existence, though you cannot either give me any reason why you believe it exists, or assign any use to it when it is supposed to exist. I say, the bare possibility of your opinions being true shall pass for an argument that it is so.

23. But, say you, surely there is nothing easier than for me to imagine trees, for instance, in a park, or books existing in a closet, and nobody by to perceive them. I answer, you may do so; there is no difficulty in it; but what is all this, I beseech you, more than framing in *your* mind certain ideas which you call books and trees, and at the same time omitting to frame the idea of any one that may perceive them? But do not you yourself perceive or think of them all the while? This therefore is nothing to the purpose: it only shews you have the power of imagining or forming ideas in your mind; but it does not shew that you can conceive it possible the objects of your thought may exist without the mind. To make out this, it is necessary that *you* conceive them existing unconceived or unthought of, which is a manifest repugnancy. When we do our utmost to conceive the existence of external bodies, we are all the while only contemplating our own ideas. But the mind, *taking no notice of itself,* is deluded to think it can and does conceive bodies existing unthought of or without the mind, though at the same time they are apprehended by or exist in itself. A little attention will discover to any one the truth and evidence of what is here said, and make it unnecessary to insist on any other proofs against the existence of *material substance.*

24. It is very obvious, upon the least inquiry into our own thoughts, to know whether it be possible for us to *understand* what is meant by the *absolute* existence of sensible objects *in themselves,* or *without the mind.* To me it is evident those words mark out either a direct contradiction, or else nothing at all. And to convince others of this, I know no readier or fairer way than to entreat they would calmly attend to their own thoughts; and if by this attention the emptiness or repugnancy of those expressions does appear, surely nothing more is requisite for their conviction. It is on this therefore that I insist, to wit, that the absolute existence of unthinking things are words without a meaning, or which include a contradiction. This is what I repeat and

inculcate, and earnestly recommend to the attentive thoughts of the reader.

25. All our ideas, sensations, motions, or the things which we perceive, by whatsoever names they may be distinguished, are visibly inactive—there is nothing of Power or Agency included in them. So that one idea or object of thought cannot produce or make any alteration in another. To be satisfied of the truth of this, there is nothing else requisite but a bare observation of our ideas. For, since they and every part of them exist only in the mind, it follows that there is nothing in them but what is perceived: but whoever shall attend to his ideas, whether of sense or reflection, will not perceive in them any power or activity; there is, therefore, no such thing contained in them. A little attention will discover to us that the very being of an idea implies passiveness and inertness in it, insomuch that it is impossible for an idea to do anything, or, strictly speaking, to be the cause of anything: neither can it be the resemblance or pattern of any active being, as is evident from sect. 8. Whence it plainly follows that extension, figure, and motion cannot be the cause of our sensations. To say, therefore, that these are the effects of powers resulting from the configuration, number, motion, and size of corpuscles, must certainly be false.

26. We perceive a continual *succession* of ideas; some are anew excited, others are changed or totally disappear. There is therefore some Cause of these ideas, whereon they depend, and which produces and changes them. That this cause cannot be any quality, or idea, or combination of ideas is clear from the preceding section. It must therefore be a substance; but it has been shown that there is no corporeal or material substance: it remains therefore that the cause of ideas is an incorporeal active substance or Spirit.

27. A Spirit is one simple, undivided, active being—as it *perceives* ideas it is called the *Understanding,* and as it *produces* or otherwise *operates* about them it is called the *Will.* Hence there can be no *idea* formed of a soul or spirit; for, all ideas whatever, being passive and inert, (vid. sect. 25,) cannot represent unto us, by way of image or likeness, that which acts. A little attention will make it plain to any one that to have an idea which shall be *like* that active principle of motion and change of ideas is absolutely impossible. Such is the nature of Spirit, or that which acts, that it cannot be of itself perceived, but only by the effects which it produceth.—If any man shall doubt of the truth of what is here delivered, let him but reflect and try if we can frame the

idea of any Power or Active Being; and whether he has ideas of two principal powers, marked by the names *Will* and *Understanding*, distinct from each other, as well as from a third idea of Substance or Being in general, with a relative motion of its supporting or being the subject of the aforesaid powers—which is signified by the name Soul or Spirit. This is what some hold; but, so far as I can see, the words *will, soul, spirit*, do not stand for different ideas, or, in truth, for any idea at all, but for something which is very different from ideas, and which, being an Agent, cannot be like unto, or represented by, any idea whatsoever. [Though it must be owned at the same time that we have some *notion* of soul, spirit, and the operation of the mind; such as willing, loving, hating—inasmuch as we know or understand the meaning of these words.]

28. I find I can excite ideas in my mind at pleasure, and vary and shift the scene as oft as I think fit. It is no more than willing, and straightway this or that idea arises in my fancy; and by the same power it is obliterated and makes way for another. This making and unmaking of ideas doth very properly denominate the mind active. Thus much is certain and grounded on experience: but when we talk of unthinking agents, or of exciting ideas exclusive of Volition, we only amuse ourselves with words.

29. But, whatever power I may have over my own thoughts, I find the ideas actually perceived by Sense have not a like dependence on my will. When in broad daylight I open my eyes, it is not in my power to choose whether I shall see or no, or to determine what particular objects shall present themselves to my view; and so likewise as to the hearing and other senses, the ideas imprinted on them are not creatures of my will. There is therefore some *other* Will or Spirit that produces them.

30. The ideas of Sense are more strong, lively, and distinct than those of the Imagination; they have likewise a steadiness, order, and coherence, and are not excited at random, as those which are the effects of human wills often are, but in a regular train or series—the admirable connexion whereof sufficiently testifies the wisdom and benevolence of its Author. Now the set rules or established methods wherein the Mind we depend on excites in us the ideas of sense, are called the *laws of nature;* and these we learn by experience, which teaches us that such and such ideas are attended with such and such other ideas, in the ordinary course of things.

31. This gives us a sort of foresight which enables us to regulate our actions for the benefit of life. And without this we should be eternally at a loss; we could not know how to act anything that might procure us the least pleasure, or remove the least pain of sense. That food nourishes, sleep refreshes, and fire warms us; that to sow in the seed-time is the way to reap in the harvest; and in general that to obtain such or such ends, such or such means are conducive—all this we know, not by discovering any *necessary connexion* between our ideas, but only by the *observation* of the settled laws of nature, without which we should be all in uncertainty and confusion, and a grown man no more know how to manage himself in the affairs of life than an infant just born.

32. And yet this consistent uniform working, which so evidently displays the goodness and wisdom of that Governing Spirit whose Will constitutes the laws of nature, is so far from leading our thoughts to Him, that it rather sends them wandering after second causes. For, when we perceive certain ideas of Sense constantly followed by other ideas, and we know this is not of our own doing, we forthwith attribute power and agency to the ideas themselves, and make one the cause of another, than which nothing can be more absurd and unintelligible. Thus, for example, having observed that when we perceive by sight a certain round luminous figure we at the same time perceive by touch the idea or sensation called heat, we do from thence conclude the sun to be the *cause* of heat. And in like manner perceiving the motion and collision of bodies to be attended with sound, we are inclined to think the latter the *effect* of the former.

33. The ideas imprinted on the Senses by the Author of nature are called *real things:* and those excited in the imagination being less regular, vivid, and constant, are more properly termed *ideas,* or *images of things,* which they copy and represent. But then our sensations, be they never so vivid and distinct, are nevertheless ideas, that is, they exist in the mind, or are perceived by it, as truly as the ideas of its own framing. The ideas of Sense are allowed to have more reality in them, that is, to be more strong, orderly, and coherent than the creatures of the mind; but this is no argument that they exist without the mind. They are also less dependent on the spirit, or thinking substance which perceives them, in that they are excited by the will of another and more powerful Spirit; yet still they are *ideas,* and certainly no idea, whether faint or strong, can exist otherwise than in a mind perceiving it.

HUME

David Hume was born at Edinburgh in April, 1711. He studied for a time at the university in the city and later began the reading of law, but forsook it for philosophical pursuits. He published his "Treatise on the Understanding" in 1739-40.

Berkeley had argued that the unknown something presupposed as the cause of sensations must be similar in nature to the self we already know and hence an intellectuality. Hume attacked all this and in fact the possibility of all philosophy and all science by maintaining that there is no self but the disconnected sensations and ideas of consciousness, that the idea of cause and effect is simply the result of habit, that all experience is personal, made up of the mental phenomena of the moment not necessarily related, and hence that all certain knowledge is impossible.

About 1741 he became interested in political subjects and his essays in that field were widely read. He argued against the idea that money, instead of men and commodities, constitutes wealth, and as a consequence against the principle that exports should exceed imports and against restricted trade. Adam Smith later adopted many of these ideas.

In 1751 he was appointed librarian of the Faculty of Advocates, and turned his attention to history. His history of England was published in the next ten years.

He became secretary to Lord Hertford, ambassador to France in 1763, and from 1767 to 1769 he was Under-Secretary of State. He died in Edinburgh August 25, 1776.

AGAINST THE PRINCIPLE OF CAUSE AND EFFECT

I am sensible how abstruse all this reasoning must appear to the generality of readers, who not being accustom'd to such profound reflections on the intellectual faculties of the mind, will be apt to reject as chimerical whatever strikes not in with the common receiv'd notions, and with the easiest and most obvious principles of philosophy. And no doubt there are some pains requir'd to enter into these arguments; tho' perhaps very little are necessary to perceive the imperfection of every vulgar hypothesis on this subject, and the little light, which philosophy can yet afford us in such sublime and such curious speculations. Let men be once fully perswaded of these two principles, *That there is nothing in any object, consider'd in itself, which can afford us a reason for drawing a conclusion beyond it;* and, *That even after the observation of the frequent or constant conjunction of objects, we have no reason to draw any inference concerning any object beyond those of which we have had experience;* I say, let men be once fully convinc'd of these two principles, and this will throw them so loose from all common systems, that they will make no difficulty of receiving any, which may appear the most extraordinary. These principles we have found to be sufficiently convincing, even with regard to our most certain reasonings from causation: But I shall venture to affirm, that with regard to these conjectural or probable reasonings they still acquire a new degree of evidence.

First, 'Tis obvious, that in reasonings of this kind, 'tis not the object presented to us, which, consider'd in itself, affords us any reason to draw a conclusion concerning any other object or event. For as this latter object is suppos'd uncertain, and as the uncertainty is deriv'd from a conceal'd contrariety of causes in the former, were any of the causes plac'd in the known qualities of that object, they wou'd no longer be conceal'd, nor wou'd our conclusion be uncertain.

But, *secondly,* 'tis equally obvious in this species of reasoning, that if the transference of the past to the future were founded merely on a conclusion of the understanding, it cou'd never occasion any belief or assurance. When we transfer contrary experiments to the future, we can only repeat these contrary experiments with their particular proportions; which cou'd not produce assurance in any single event, upon which we reason, unless the fancy melted together all those images that concur, and extracted from them one single idea or image, which is intense and lively in proportion to the number of experiments from which it is deriv'd, and their superiority above their antagonists. Our past experience presents no determinate object; and as our belief, however faint, fixes itself on a determinate object, 'tis evident that the belief arises not merely from the transference of past to future, but from some operation of the *fancy* conjoin'd with it. This may lead us to conceive the manner in which that faculty enters into all our reasonings.

I shall conclude this subject with two reflections, which may deserve our attention. The *first* may be explain'd after this manner. When the mind forms a reasoning concerning any matter of fact, which is only probable, it casts its eye backward upon past experience, and transferring it to the future, is presented with so many contrary views of its object, of which those that are of the same kind uniting together, and running into one act of the mind, serve to fortify and inliven it. But suppose that this multitude of views or glimpses of an object proceeds not from experience, but from a voluntary act of the imagination; this effect does not follow, or at least, follows not in the same degree. For tho' custom and education produce belief by such a repetition, as is not deriv'd from experience, yet this requires a long tract of time, along with a very frequent and *undesign'd repetition.* In general we may pronounce, that a person, who wou'd *voluntarily* repeat any idea in his mind, tho' supported by one past experience, wou'd be no more inclin'd to believe the existence of its object, than if he had contented himself with one survey of it. Beside the effect of design; each act of the mind, being separate and independent, has a separate influence, and joins not its force with that of its fellows. Not being united by any common object, producing them, they have no relation to each other; and consequently make no transition or union of forces. This phænomenon we shall understand better afterwards.

My *second* reflection is founded on those large probabilities, which the mind can judge of, and the minute differences it can observe betwixt them. When the chances or experiments on one side amount to ten thousand, and on the other to ten thousand and one, the judgment gives the preference to the latter, upon account of that superiority; tho' 'tis plainly impossible for the mind to run over every particular view, and distinguish the superior vivacity of the image arising from the superior number, where the difference is so inconsiderable. We have a parallel instance in the affections. 'Tis evident, according to the principles above-mention'd, that when an object produces any passion in us, which varies according to the different quantity of the object; I say, 'tis evident, that the passion, properly speaking, is not a simple emotion, but a compounded one, of a great number of weaker passions, deriv'd from a view of each part of the object. For otherwise 'twere impossible the passion shou'd encrease by the encrease of these parts. Thus a man, who desires a thousand pound, has in reality a thousand or more desires, which uniting together, seem to make only one passion; tho' the composition evidently betrays itself upon every alteration of the object, by the preference he gives to the larger number, if superior only by an unit. Yet nothing can be more certain, than that so small a difference wou'd not be discernible in the passions, nor wou'd render them distinguishable from each other. The difference, therefore, of our conduct in preferring the greater number depends not upon our passions, but upon custom, and *general rules.* We have found in a multitude of instances, that the augmenting the numbers of any sum augments the passion, where the numbers are precise and the difference sensible. The mind can perceive from its immediate feeling, that three guineas produce a greater passion than two; and *this* it transfers to larger numbers, because of the resemblance; and by a general rule assigns to a thousand guineas, a stronger passion than to nine hundred and ninety-nine. These general rules we shall explain presently.

But beside these two species of probability, which are deriv'd from an *imperfect* experience and from *contrary* causes, there is a third arising from ANALOGY, which differs from them in some material circumstances. According to the hypothesis above explain'd all kinds of reasoning from causes or effects are founded on two particulars, *viz.*, the constant conjunction of any two objects in all past experience, and the resemblance of a present object to any one of them. The effect of these two particulars is, that the present object invigorates and enlivens the imagination; and the resemblance, along with the constant union, conveys this force and vivacity to the related idea; which we are therefore said to believe, or assent to. If you weaken either the union or resemblance, you weaken the principle of transition, and of consequence that belief, which arises from it. The vivacity of the first impression cannot be fully convey'd to the related idea, either where the conjunction of their objects is not constant, or where the present impression does not perfectly resemble any of those, whose union we are accustom'd to observe. In those probabilities of chance and causes above-explain'd, 'tis the constancy of the union, which is diminish'd; and in the probability deriv'd from analogy, 'tis the resemblance only, which is affected. Without some degree of resemblance, as well as union, 'tis impossible there can be any reasoning: but as this resemblance admits of many different degrees, the reasoning becomes proportionately more or less firm and certain. An experiment loses of its force, when tranferr'd to instances, which are not exactly resembling; tho' 'tis evident it may still retain as much as may be the foundation of probability, as long as there is any resemblance remaining.

AGAINST PERSONAL IDENTITY

There are some philosophers who imagine we are every moment intimately conscious of what we call our SELF; that we feel its existence and its continuance in existence; and are certain, beyond the evidence of a demonstration, both of its perfect identity and simplicity. The strongest sensation, the most violent passion, say they, instead of distracting us from this view, only fix it the more intensely, and make us consider their influence on *self* either by their pain or pleasure. To attempt a farther proof of this were to weaken its evidence; since no proof can be deriv'd from any fact, of which we are so intimately conscious; nor is there any thing, of which we can be certain, if we doubt of this.

Unluckily all these positive assertions are contrary to that very experience, which is pleaded for them, nor have we any idea of *self*, after the manner it is here explain'd. For from what impression cou'd this idea be deriv'd? This question 'tis impossible to answer without a manifest contradiction and absurdity; and yet 'tis a question, which must necessarily be answer'd, if we wou'd have the idea of self pass for clear and intelligible. It must be some one impression, that gives rise to every real idea. But self or person is not any one impression, but that to which our several impressions and ideas are suppos'd to have a reference. If any impression gives rise to the idea of self, that impression must continue invariably the same, thro' the whole course of our lives; since self is suppos'd to exist after that manner. But there is no impression constant and invariable. Pain and pleasure, grief and joy, passions and sensations succeed each other, and never all exist at the same time. It cannot, therefore, be from any of these impressions, or from any other, that the idea of self is deriv'd; and consequently there is no such idea.

But farther, what must become of all our particular perceptions upon this hypothesis? All these are different, and distinguishable, and separable from each other, and may be separately consider'd, and may exist separately, and have no need of any thing to support their existence. After what manner, therefore, do they belong to self; and how are they connected with it? For my part, when I enter most intimately into what I call *myself*, I always stumble on some particular perception or other, of heat or cold, light or shade, love or hatred, pain or pleasure. I never can catch *myself* at any time without a perception, and never can observe any thing but the perception. When my perceptions are remov'd for any time, as by sound sleep; so long am I insensible of myself, and may truly be said not to exist. And were all my perceptions remov'd by death, and cou'd I neither think, nor feel, nor see, nor love, nor hate after the dissolution of my body. I shou'd be entirely annihilated, nor do I conceive what is farther requisite to make me a perfect non-entity. If any one upon serious and unprejudic'd reflection, thinks he has a different notion of himself, I must confess I can reason no longer with him. All I can allow him is, that he may be in the right as well as I, and that we are essentially different in this particular. He may, perhaps, perceive something simple and continu'd, which he calls himself, tho' I am certain there is no such principle in me.

But setting aside some metaphysicians of this kind, I may venture to affirm of the rest of mankind, that they are nothing but a bundle or collection of different perceptions, which succeed each other with an inconceivable rapidity, and are in a perpetual flux and movement. Our eyes cannot turn in their sockets without varying our perceptions. Our thought is still more variable than our sight; and all our other senses and faculties contribute to this change; nor is there any single power of the soul, which remains unalterably the same, perhaps for one moment. The mind is a kind of theater, where several perceptions successively make their appearance; pass, re-pass, glide away, and mingle in an infinite variety of postures and situations. There is properly no simplicity in it at one time, nor identity in different; whatever natural propension we may have to imagine that simplicity and identity. The comparison of the theater must not lead us. They are the successive perceptions only, that constitute the mind; nor have we the most distant notion of the place, where these scenes are represented, or of the materials, of which it is compos'd.

What then gives us so great a propension to ascribe an identity to these successive perceptions, and to suppose ourselves possest of an invariable and uninterrupted existence thro' the whole course of our lives? In order to answer this question, we must distinguish betwixt personal identity, as it regards our thought or imagination, and as it regards our passions or the concern we take in ourselves. The first is our present subject; and to explain it perfectly we must take the matter pretty deep, and account for that identity, which we attribute to plants and animals; there being a great analogy betwixt it, and the identity of a self or person.

We have a distinct idea of an object, that remains invariable and uninterrupted thro' a suppos'd variation of time; and this idea we call that of identity or sameness. We have also a distinct idea of several different objects existing in succession, and connected together by a close relation; and this to an accurate view affords as perfect a notion of diversity, as if there was no manner of relation among the objects. But tho' these two ideas of identity, and a succession of related objects be in themselves perfectly distinct, and even contrary, yet 'tis certain, that in our common way of thinking they are generally confounded with each other. That action of the imagination, by which we consider the uninterrupted and invariable object, and that by which we reflect on the succession of related objects, are almost the same to the feeling, nor is there much more effort of thought requir'd in the latter case than in the former. The relation facilitates the transition of the mind from one object to another, and renders its passage as smooth as if it contemplated one continu'd object. This resemblance is the cause of the confusion and mistake, and makes us substitute the notion of identity, instead of that of related objects. However at one instant we may consider the related succession as variable or interrupted, we are sure the next to ascribe to it a perfect identity, and regard it as invariable and uninterrupted. Our propensity to this mistake is so great from the resemblance above-mention'd, that we fall into it before we are aware; and tho' we incessantly correct ourselves by reflection, and return to a more accurate method of thinking, yet we cannot long sustain our philosophy, or take off this biass from the imagination. Our last resource is to yield to it, and boldly assert that these different related objects are in effect the same, however interrupted and variable. In order to justify to ourselves this absurdity, we often feign some new and unintelligible principle, that connects the objects together, and prevents their interruption or variation. Thus we feign the continu'd existence of the perceptions of our senses, to remove the interruption; and run into the notion of a soul, and self, and substance, to disguise the variation. But we may farther observe, that where we do not give rise to such a fiction, our propension to confound identity with relation is so great, that we are apt to imagine something unknown and mysterious, connecting the parts, beside their relation; and this I take to be the case with regard to the identity we ascribe to plants and vegetables. And even when this does not take place, we still feel a propensity to confound these ideas, tho' we are not able fully to satisfy ourselves in that particular, nor find any thing invariable and uninterrupted to justify our notion of identity.

Thus the controversy concerning identity is not merely a dispute of words. For when we attribute identity, in an improper sense, to variable or interrupted objects, our mistake is not confin'd to the expression, but is commonly attended with a fiction, either of something invariable and uninterrupted, or of something mysterious and inexplicable, or at least with a propensity to such fictions. What will suffice to prove this hypothesis to the satisfaction of every fair enquirer, is to shew from daily experience and observation, that the objects, which are variable or interrupted, and yet are suppos'd to continue the same, are such only as consist of a succession of parts, connected together by resemblance, contiguity, or causation. For as such a succession answers evidently to our notion of diversity, it can only be by mistake we ascribe to it an identity; and as the relation of parts, which leads us into this mistake, is really nothing but a quality, which produces an association of ideas, and an easy transition of the imagination from one to another, it can only be from the resemblance, which this act of the mind bears to that, by which we contemplate one continu'd object, that the error arises. Our chief business, then, must be to prove, that all objects, to which we ascribe identity, without observing their invariableness and uninterruptedness, are such as consist of a succession of related objects.

In order to this, suppose any mass of matter, of which the parts are contiguous and connected, to be plac'd before us; 'tis plain we must attribute a perfect identity to this mass, provided all the parts continue uninterruptedly and invariably the same, whatever motion or change of place we may observe either in the whole or in any of the parts. But supposing some very small or inconsiderable part to be added to the mass, or substracted from it; tho' this absolutely destroys the identity of the whole, strictly speaking; yet as we seldom think so accurately, we scruple not to pronounce a mass of matter the same, where we find so trivial an alteration. The passage of the thought from the object before the change to the object after it, is so smooth and easy, that we scarce perceive the transition, and are apt to imagine that 'tis nothing but a continu'd survey of the same object.

There is a very remarkable circumstance, that attends this experiment; which is, that tho' the change of any considerable part in a mass of matter destroys the identity of the whole, yet we must measure the greatness of the part, not absolutely, but by its proportion to the whole. The addition or diminution of a mountain wou'd not be sufficient to produce a diversity in a planet; tho' the change of a very few inches wou'd be able to destroy the identity of some bodies. 'Twill be impossible to account for this, but by reflecting that objects operate upon the mind, and break or interrupt the continuity of its actions not according to their real greatness, but according to their proportion to each other: And therefore, since this interruption makes an object cease to appear the same, it must be the uninterrupted progress of the thought, which constitutes the [im]perfect identity.

This may be confirm'd by another phænomenon. A change in any considerable part of a body destroys its identity; but 'tis remarkable, that where the change is produc'd gradually and insensibly we are less apt to ascribe to it the same effect. The reason can plainly be no other, than that the mind, in following the successive changes of the body, feels an easy passage from the surveying its condition in one moment to the viewing of it in another, and at no particular time perceives any interruption in its actions. From which continu'd perception, it ascribes a continu'd existence and identity to the object.

But whatever precaution we may use in introducing the changes gradually, and making them proportionable to the whole, 'tis certain, that where the changes are at last observ'd to become considerable, we make a scruple of ascribing identity to such different objects. There is, however, another artifice, by which we may induce the imagination to advance a step farther; and that is, by producing a reference of the parts to each other, and a combination to some common end or purpose. A ship, of which a considerable part has been chang'd by frequent reparations, is still consider'd as the same; nor does the difference of the materials hinder us from ascribing an identity to it. The common end, in which the parts conspire, is the same under all their variations, and affords an easy transition of the imagination from one situation of the body to another.

But this is still more remarkable, when we add a sympathy of parts to their common end, and suppose that they bear to each other, the reciprocal relation of cause and effect in all their actions and operations. This is the case with all animals and vegetables; where not only the several parts have a reference to some general purpose, but also a mutual dependence on, and connection with each other. The effect of so strong a relation is, that tho' every one must allow, that in a very few years both vegetables and animals endure a total change, yet we still attribute identity to them, while their form, size, and substance are entirely alter'd. An oak, that grows from a small plant to a large tree, is still the same oak; tho' there be not one particle of matter, or figure of its parts the same. An infant becomes a man, and is sometimes fat, sometimes lean, without any change in his identity.

We may also consider the two following phænomena, which are remarkable in their kind. The first is, that tho' we commonly be able to distinguish pretty exactly betwixt numerical and specific identity, yet it sometimes happens, that we confound them, and in our thinking and reasoning employ the one for the other. Thus a man, who hears a noise, that is frequently interrupted and renew'd, says, it is still the same noise; tho' 'tis evident the sounds have only a specific identity or resemblance, and there is nothing numerically the same, but the cause, which produc'd them. In like manner it may be said without breach of the propriety of language, that such a church, which was formerly of brick, fell to ruin, and that the parish rebuilt the same church of free-stone, and according to modern architecture. Here neither the form nor materials are the same, nor is there any thing common to the two objects, but their relation to the inhabitants of the parish; and yet this alone is sufficient to make us denominate them the same. But we must observe, that in these cases the first object is in a manner annihilated before the second comes into existence; by which means, we are never presented in any one point of time with the idea of difference and multiplicity; and for that reason are less scrupulous in calling them the same.

Secondly, We may remark, that tho' in a succession of related objects, it be in a manner requisite, that the change of parts be not sudden nor entire, in order to preserve the identity, yet where the objects are in their nature changeable and inconstant, we admit of a more sudden transition, than wou'd otherwise be consistent with that relation. Thus as the nature of a river consists in the motion and change of parts; tho' in less than four and twenty hours these be totally alter'd; this hinders not the river from continuing the same during several ages. What is natural and essential to any thing is, in a manner, expected;

and what is expected makes less impression, and appears of less moment, than what is unusual and extraordinary. A considerable change of the former kind seems really less to the imagination, than the most trivial alteration of the latter; and by breaking less the continuity of the thought, has less influence in destroying the identity.

We now proceed to explain the nature of personal identity, which has become so great a question in philosophy, especially of late years in England, where all the abstruser sciences are study'd with a peculiar ardour and application. And here 'tis evident, the same method of reasoning must be continu'd, which has so successfully explain'd the identity of plants, and animals, and ships, and houses, and of all the compounded and changeable productions either of art or nature. The identity, which we ascribe to the mind of man, is only a fictitious one, and of a like kind with that which we ascribe to vegetables and animal bodies. It cannot, therefore, have a different origin, but must proceed from a like operation of the imagination upon like objects.

But lest this argument should not convince the reader; tho' in my opinion perfectly decisive; let him weigh the following reasoning, which is still closer and more immediate. 'Tis evident that the identity, which we attribute to the human mind, however perfect we may imagine it to be, is not able to run the several different perceptions into one, and make them lose their characters of distinction and difference, which are essential to them. 'Tis still true, that every distinct perception, which enters into the composition of the mind, is a distinct existence, and is different and distinguishable, and separable from every other perception, either contemporary or succesive. But, as, notwithstanding this distinction and separably, we suppose the whole train of perceptions to be united by identity, a question naturally arises concerning this relation of identity; whether it be something that really binds our several perceptions together, or only associates their ideas in the imagination. That is, in other words, whether in pronouncing concerning the identity of a person, we observe some real bond among his perceptions, or only feel one among the ideas we form of them. This question we might easily decide if we wou'd recollect what has been already prov'd at large, that the understanding never observes any real connexion among objects, and that even the union of cause and effect, when strictly examin'd, resolves itself into a customary association of ideas. For from thence it evidently follows, that identity is nothing really belonging to these different perceptions and uniting them together; but is merely a quality, which we attribute to them, because of the union of their ideas in the imagination, when we reflect upon them. Now the only qualities which can give ideas an union in the imagination, are these three relations above mentioned. These are the uniting principles in the ideal world, and without them every distinct object is separable by the mind, and may be separately considered, and appears not to have any more connection with any other object than if disjoined by the greatest difference and remoteness. 'Tis, therefore, on some of these three relations of resemblance, contiguity and causation that identity depends; and as the very essence of these relations consists in their producing an easy transition of ideas; it follows, that our notions of personal identity proceed entirely from the smooth and uninterrupted progress of the thought along a train of connected ideas, according to the princples above explained.

The only question, therefore, which remains, is, by what relations this uninterrupted progress of our thought is produc'd when we consider the successive existence of a mind or thinking person. And here 'tis evident we must confine ourselves to resemblance and causation, and must drop contiguity, which has little or no influence in the present case.

To begin with resemblance; suppose we could see clearly into the breast of another, and observe that succession of perceptions, which constitutes his mind or thinking principle, and suppose that he always preserves the memory of a considerable part of past perceptions; 'tis evident that nothing cou'd more contribute to the bestowing a relation on this succession amidst all its variations. For what is the memory but a faculty, by which we raise up the images of past perceptions? And as an image necessarily resembles its object, must not the frequent placing of these resembling perceptions in the chain of thought, convey the imagination more easily from one link to another and make the whole seem like the continuance of one object? In this particular, then, the memory not only discovers the identity, but also contributes to its production, by producing the relation of resemblance among the perceptions. The case is the same whether we consider ourselves or others.

As to causation; we may observe that the true idea of the human mind is to consider it as a system of different perceptions or different existences, which are linked together by the relation of cause and effect, and mutually produce, destroy, influence and modify each other. Our impressions give rise to their correspondent ideas; and these ideas in their turn produce other impressions. One thought chases another and draws after it a third, by which it is expelled in its turn. In this respect, I cannot compare the soul more properly to any thing than to a republic or commonwealth in which the several members are united by the reciprocal ties of government and subordination, and give rise to other persons, who propagate the same republic in the incessant changes of its parts. And as the same individual republic may not only change its members, but also its laws and constitutions; in like manner the same person may vary his character and disposition, as well as his impressions and ideas, without losing his identity. Whatever changes he endures, his several parts are still connected by the relation of causation. And in this view our identity with regard to the passions serves to corroborate that with regard to the imagination, by the making our distant perceptions influence each other, and by giving us a present concern for our past or future pains or pleasures.

As memory alone acquaints us with the continuance and extent of this succession of perceptions, 'tis to be consider'd, upon that account chiefly, as the source of personal identity. Had we no memory, we never should have any notion of causation, nor consequently of that chain of causes and effects, which constitute our self or person. But having once acquir'd this notion of causation from the memory, we can extend the same chain of causes, and consequently the identity of our persons beyond our memory, and can comprehend times, and circumstances, and actions, which we have entirely forgot, but suppose in general to have existed. For how few of our past actions are there of which we have any memory? Who can tell me, for instance, what were his thoughts and actions on the first of January, 1715, the 11th of March, 1719, and the 3d of August, 1733? Or will he affirm, because he has entirely forgot the incidents of these days that the present self is not the same person with the self of that time; and by that means overturn all the most establish'd notions of personal identity? In this view, therefore, memory does not so much produce as discover personal identity, by shewing us the relation of cause and effect among our different perceptions. 'Twill be incumbent on those, who affirm that memory produces entirely our personal identity, to give a reason why we can thus extend our identity beyond our memory.

The whole of this doctrine leads us to a conclusion, which is of great importance in the present affair, *viz.* that all the nice and subtile questions concerning personal identity can never possibly be decided, and are to be regarded rather as grammatical than as philosophical difficulties. Identity depends on the relations of ideas; and these relations produce identity by means of that easy transition they occasion. But as the relations and the easiness of the transition may diminish by insensible degrees, we have no just standard by which we can decide any dispute concerning the time when they acquire or lose a title to the name of identity. All the disputes concerning the identity of connected objects are merely verbal, except so far as the relation of parts gives rise to some fiction or imaginary principle of union, as we have already observed.

What I have said concerning the first origin and uncertainty of our notion of identity, as applied to the human mind, may be extended with little or no variation to that of simplicity. An object, whose different co-existent parts are bound together by a close relation, operates upon the imagination after much the same manner as one perfectly simple and undivisible, and requires not a much greater stretch of thought in order to its conception. From this similarity of operation we attribute a simplicity to it, and feign a principle of union as the support of this simplicity and the center of all the different parts and qualities of the object.

Thus we have finished our examination of the several systems of philosophy, both of the intellectual and moral world; and in our miscellaneous way of reasoning have been led into several topics; which will either illustrate and confirm some preceding part of this discourse, or prepare the way for our following opinions. 'Tis now time to return to a more close examination of our subject and to proceed in the accurate anatomy of human nature, having fully explained the nature of our judgment and understanding.

Note on the Above

I had entertained some hopes, that however deficient our theory of the intellectual world might be, it would be free from those contradictions and absurdities which seem to attend every explication that human reason can give of the material world. But upon a more strict review of the section concerning personal identity I find myself involved in such a labyrinth, that, I must confess, I neither know how to correct my former opinions, nor how to render them consistent. If this be not a good general reason for scepticism, 'tis at least a sufficient one (if I were not already abundantly supplied) for me to entertain a diffidence and modesty in all my decisions. I shall propose the arguments on both sides, beginning with those that induced me to deny the strict and proper identity and simplicity of a self or thinking being.

When we talk of self for substance, we must have an idea annexed to these terms, otherwise they are altogether unintelligible. Every idea is derived from preceding impressions; and we have no impression of self or substance, as something simple and individual. We have, therefore, no idea of them in that sense.

Whatever is distinct, is distinguishable; and whatever is distinguishable is separable by the thought or imagination. All perceptions are distinct. They are, therefore, distinguishable and separable, and may be conceived as separately existent, and may exist separately, without any contradiction or absurdity.

When I view this table and that chimney, nothing is present to me but particular perceptions, which are of a like nature with all the other perceptions. This is the doctrine of philosophers. But this table, which is present to me, and that chimney, may and do exist separately. This is the doctrine of the vulgar, and implies no contradiction. There is no contradiction, therefore, in extending the same doctrine to all the perceptions.

In general the following reasoning seems satisfactory. All ideas are borrow'd from preceding perceptions. Our ideas of objects, therefore, are deriv'd from that source. Consequently no proposition can be intelligible or consistent with regard to objects, which is not so with regard to perceptions. But 'tis intelligible and consistent to say, that objects exist distinct and independent, without any common simple substance or subject of inhesion. This proposition, therefore, can never be absurd with regard to perceptions.

When I turn my reflection on myself, I never can perceive this self without some one or more perceptions; nor can I ever perceive any thing but the perceptions. 'Tis the composition of these, therefore, which forms the self.

We can conceive a thinking being to have either many or few perceptions. Suppose the mind to be reduc'd even below the life of an oyster. Suppose it to have only one perception, as of thirst or hunger. Consider it in that situation. Do you conceive any thing but merely that perception? Have you any notion of self or substance? If not, the addition of other perceptions can never give you that notion.

The annihilation, which some people suppose to follow upon death, and which entirely destroys this self, is nothing but an extinction of all particular perceptions; love and hatred, pain and pleasure, thought and sensation. These therefore must be the same with self; since the one cannot survive the other.

Is self the same with substance? If it be, how can that question have place, concerning the subsistence of self, under a change of substance? If they be distinct, what is the difference betwixt them? For my part, I have a notion of neither, when conceiv'd distinct from particular perceptions.

Philosophers begin to be reconciled to the principle, that we have no idea of external substance, distinct from the ideas of particular qualities. This must pave the way for a like principle with regard to the mind, that we have no notion of it, distinct from the particular perceptions.

So far I seem to be attended with sufficient evidence. But having thus loosen'd all our particular perceptions, when I proceed to explain the principle of connexion, which binds them together, and makes us attribute to them a real simplicity and identity; I am sensible, that my account is very defective, and that nothing but the seeming evidence of the precedent reasonings cou'd have induc'd me to receive it. If perceptions are distinct existences, they form a whole only by being connected together. But no connexions among distinct existences are ever discoverable by human understanding. We only feel a connexion or determination of the thought, to pass from one object to another. It follows, therefore, that the thought alone finds personal identity. When reflecting on the train of past perceptions that compose a mind the ideas of them are felt to be connected together, and naturally introduce each other. However extraordinary this conclusion may seem, it need not surprize us. Most philosophers seem inclin'd to think, that personal identity arises from consciousness; and consciousness is nothing but a reflected thought or perception. The present philosophy, therefore, has so far a promising aspect. But all my hopes vanish, when I come to explain the principles, that unite our successive perceptions in our thought or consciousness. I cannot discover any theory, which gives me satisfaction on this head.

In short there are two principles, which I cannot render consistent; nor is it in my power to renounce either of them, viz. *that all our distinct perceptions are distinct existences,* and *that the mind never perceives any real connexion among distinct existences.* Did our perceptions either inhere in something simple and individual, or did the mind perceive some real connexion among them, there wou'd be no difficulty in the case. For my part, I must plead the privilege of a sceptic, and confess that this difficulty is too hard for my understanding. I pretend not, however, to pronounce it absolutely insuperable. Others, perhaps, or myself, upon more mature reflections, may discover some hypothesis, that will reconcile those contradictions.

KANT

IMMANUEL KANT was born at Koenigsberg, Prussia, April 22, 1724. His father was of Scottish descent. From 1740 to 1746 Kant studied theology, and for the next nine years made his living as a tutor. In 1755 he returned to the university at Koenigsberg, and after receiving his doctor's degree, acted as a *privat docent* until 1770, when he was appointed Prof. of Logic and Metaphysics. He never married, although of a social disposition, and never left his native city, unless in a brief walk into the country. He died February 12, 1804.

In 1754 he noted the slight retardation of the earth's motion on account of the tides. In the next year he suggested a nebular hypothesis of the origin of the universe, thus really antedating Laplace. His most important work is, however, the *Critique of Pure Reason,* published in 1781. The *Critique of Practical Reason* followed in 1788 and the *Critique of Judgment* in 1790. The three form the starting point of our philosophy to-day.

Kant saw that on the one hand the continental philosophy had developed into dogmatic speculation, and that on the other English philosophy, starting from Locke's assumption that all knowledge comes from experience, that is, from sensation and subsequent reflection, had developed into a scepticism that denied the possibility of anything more than probable knowledge. Kant set himself to re-examine that basis of knowledge and the elements of the mind. He wanted to account for the possibility of mathematics and natural science, and to discover whether metaphysics is possible at all. His solution of the problem is briefly this: The matter of knowledge comes from experience, the form is furnished by the active mind itself. Space, time, and the various relations, such as substance and accident or cause and effect, are forms given to our knowledge by the mind. They must apply to anything we can experience, but we cannot know whether they apply to things in themselves. Mathematics is possible because we analyze space and time, which are mental; physics is possible because all experience must be subject to cause and effect, the quantitative relations, and the like, all of which are laws of the understanding. Reason's laws hold good for all experience but they cannot be applied to things we cannot experience. Things in themselves we do not know; we cannot indubitably demonstrate the existence or nature of God or the angels. Though all experience rests on the unifying activity of the self or apperception, yet the soul is outside of experience and these laws do not apply to it. Hence the soul, and God, and things in their higher reality are left free and unconfined by human law.

Kant died in 1804, but his thought is still the most important factor in philosophy. Most of the steps taken since have had to be retraced, and any future philosophy will be indebted to his analysis of the elements of knowledge. This is no place to attempt a criticism of his system, but we will take the liberty to suggest a few points for thought. If cause and effect together with space, time, etc., is merely a mental form, not to be applied at all outside of experience, has Kant the right to presuppose things in themselves at all as a cause of our sensations, seeing that we cannot directly experience them, but can argue their existence only thro' the idea of cause and effect? If not, he would be forced into idealism. On the other hand, the reasons are growing stronger for supposing that there is a close correspondence, or rather concomitant variation, between our perceptions and nature. The more science discovers, the less room there is left for freedom from the laws of experience in so-called physical nature. As philosophy must account for the possibility of science, and hence may use its results as data, we may ask whether on the principle of evolution any race would have survived whose fundamental mental life, upon which it had to act in regard to its environment, was entirely at variance with reality? Would not the law of the survival of the fittest eventually make such fundamental conceptions of the race as time and space an index of reality? To sum up our question on this point, isn't it possible for the various relations to be mental and at the same time closely represent reality? But further discussion and the philosophy since Kant's time must be reserved for another volume.

THE PROLEGOMENA

These Prolegomena are for the use, not of pupils, but of mature teachers, and are intended to serve even the latter, not in arranging their exposition of an existing science, but in discovering the science itself.

There are learned men, to whom the history of philosophy (both ancient and modern) is philosophy itself; for such the present Prolegomena are not written. They must wait till those who endeavour to draw from the fountain of reason itself have made out their case; it will then be the historian's turn to inform the world of what has been done. Moreover, nothing can be said, which in their opinion has not been said already, and indeed this may be applied as an infallible prediction to all futurity; for as the human reason has for many centuries pursued with ardour infinitely various (2) objects in various ways, it is hardly to be expected that we should not be able to match every new thing with some old thing not unlike it.

My object is to persuade all who think Metaphysic worth studying that it is absolutely necessary to adjourn for the present this (historical) labour, to consider all that has been done as undone, and to start first of all with the question, 'Whether such a thing as metaphysic be at all possible?'

If it be a science, how comes it that it cannot, like other sciences, obtain for itself an universal and permanent recognition? If not, how is it ever making constant pretensions, under this supposition, and keeping the human mind in suspense with hopes that never fade, and yet are never fulfilled? Whether then, as a result, we demonstrate our knowledge or our ignorance, we must come once for all to a definite conclusion about the nature of this pretended science, which cannot possibly remain on its present footing. It seems almost ridiculous, while every other science is continually advancing, that in this, which would be very Wisdom, at whose oracle all men inquire, we should perpetually revolve round the same point, without gaining a single step. And so its followers having melted away, we do not find men who feel able to shine in other sciences venturing their reputation here, where everybody, however ignorant in other matters, pretends to deliver a final verdict, as in this domain (3) there is as yet no certain weight and measure to distinguish sound knowledge from shallow talk.

But after long elaboration of a science, when men begin to wonder how far it has advanced, it is not without precedent that the question should at last occur, whether and how such a science be even possible? For the human reason is so constructive, that it has already several times built up a tower, and then razed it to examine the nature of the foundation. It is never too late to mend; but if the change comes late, there is always more difficulty in setting it going.

The question whether a science be possible presupposes a doubt as to its actuality. But such a doubt offends the men whose whole possessions consist of this supposed jewel; hence he who raises the doubt must expect opposition from all sides. Some, in the proud consciousness of their possessions, which are ancient, and therefore considered legitimate, will take their metaphysical compendia in their hands, and look down on him with contempt; others, who never see anything except it be identical with what they have seen before, will not understand him, and everything will remain for a time, as if nothing had happened to excite the concern, or the hope, for an impending change.

Nevertheless, I venture to predict that the independent reader of these Prolegomena will not only doubt his previous science, but ultimately be (4) fully persuaded, that it cannot exist without satisfying the demands here stated, on which its possibility depends; and, as this has never been done, that there is, as yet, no such thing as Metaphysic. But as it can never cease to be in demand—

> 'Rusticus expectat, dum defluat amnis, at ille
> Labitur et labetur in omne volubilis aevum;'—

since the interests of mankind are interwoven with it so intimately, he must confess that a radical reform, or rather a new birth of the science after an original plan, must be unavoidably at hand, however men may struggle against it for a while.

Since the Essays of Locke and Leibnitz, or rather since the origin of metaphysic so far as we know its history, nothing has ever happened which might have been more decisive to the fortunes of the science than the attack made upon it by David Hume. He threw no light on this species of knowledge, but he certainly struck a spark from which light might have been obtained, had it caught a proper substance to nurture and develop the flame.

Hume started chiefly from a single but important concept in Metaphysic—that of Cause and Effect (including the deduced notions of action and power). He calls on reason, which pretends to have generated this notion from itself, to answer him with what right it thinks anything to be so constituted, that if granted, something else must necessarily be [5] granted thereby; for this is the meaning of the concept of cause. He demonstrated irresistibly that it was perfectly impossible for reason to think such a combination by means of concepts and *a priori*—a combination that contains necessity. We cannot at all see why, in consequence of the existence of one thing, another must necessarily exist, or how the concept of such a combination can arise *a priori*. Hence he inferred, that reason was altogether deluded by this concept, which it considered erroneously as one of its children, whereas in reality the concept was nothing but the bastard offspring of the imagination, impregnated by experience, and so bringing certain representations under the Law of Association. The subjective necessity, that is, the custom which so arises, is then substituted for an objective necessity from real knowledge. Hence he inferred that the reason had no power to think such combinations, even generally, because its concepts would then be mere inventions, and all its pretended *a priori* cognitions nothing but common experiences marked with a false stamp. In plain language there is not, and cannot be, any such thing as metaphysic at all. This conclusion, however [6] hasty and mistaken, was at least founded upon investigation, and the investigation deserved to have suggested to the brighter spirits of his day a combined attempt at a happy solution of the problem proposed by him, if such solution were possible. Thus a complete reform of the science must have resulted.

But the perpetual hard fate of metaphysic would not allow him to be understood. We cannot without a certain sense of pain consider how utterly his opponents, Reid, Oswald, Beattie, and even Priestley, missed the point of the problem. For while they were ever assuming as conceded what he doubted, and demonstrating with eagerness and often with arrogance what he never thought of disputing, they so overlooked his indication toward a better state of things, that everything remained undisturbed in its old condition.

The question was not whether the concept of cause was right, useful, and even indispensable with regard to our knowledge of nature, for this Hume [7] had never doubted. But the question to which Hume expected an answer was this, whether that concept could be thought by the reason *a priori*, and whether it consequently possessed an inner truth, independent of all experience, and therefore applied more widely than to the mere objects of experience. It was surely a question concerning the origin, not concerning the indispensable use of the concept. Had the former question been determined, the conditions of the use and valid application of the concept would have been given *ipso facto*.

But the opponents of the great thinker should have probed very deeply into the nature of the reason, so far as it concerns pure thinking, if they would satisfy the conditions of the problem--a task which did not suit them. They therefore discovered a more convenient means of putting on a bold face without any proper insight into the question, by appealing to the common sense of mankind. It is indeed a great gift of God, to possess right, or (as they now call it) plain common sense. But this common sense must be shown practically, by well-considered and reasonable thoughts and words, not by appealing to it as an oracle, when you can advance nothing rational in justification of yourself. To appeal to common sense, when insight and science fail, and no sooner—this is one of the subtle discoveries of modern times, by means of which the most vapid babbler can safely enter the lists with the most thorough-[8]going thinker, and hold his own. But as long as a particle of insight remains, no one would think of having recourse to this subterfuge. For what is it, but an appeal to the opinion of the multitude, of whose applause the philosopher is ashamed, while the popular and superficial man glories and confides in it? I should think Hume might fairly have laid as much claim to sound sense as Beattie, and besides to a critical understanding (such as the latter did not possess), which keeps common sense within such limits as to prevent it from speculating, or if it does speculate, keeps it from wishing to decide when it cannot satisfy itself concerning its own principles. By this means alone can common sense remain sound sense. Chisels and hammers may suffice to work a piece of wood, but for steel-engraving we require a special instrument. Thus common sense and speculative understanding are each serviceable in their own way, the former in judgments which apply immediately to experience, the latter when we judge universally from mere concepts, as in metaphysic, where that which calls itself (often *per antiphrasin*) sound common sense has no right to judge at all.

I honestly confess, the suggestion of David Hume was the very thing which many years ago first interrupted my dogmatic slumber, and gave my investigations in the field of speculative philosophy quite a new direction. I was far from following him [9] in all his conclusions, which only resulted from his regarding not the whole of his problem, but a part, which by itself can give us no information. If we start from a well-founded, but undeveloped, thought, which another has bequeathed to us, we may well hope by continued reflection to advance farther than the acute man, to whom we owe the first spark of light.

I therefore first tried whether Hume's objection could not be put into a general form, and soon found that the concept of the connexion of cause and effect was by no means the only one by which the understanding thinks the connexion of things *a priori,* but rather that metaphysic consists altogether of such connexions. I sought to make certain of their number, and when I had succeeded in this to my expectation, by starting from a single principle, I proceeded to the deduction of these concepts, which I was now certain were not deduced from experience, as Hume had apprehended, but sprang from the pure understanding. This deduction, which seemed impossible to my acute predecessor, which had never even occurred to any one else, though they were all using the concepts unsuspiciously without questioning the basis of their objective validity—this deduction was the most difficult task ever undertaken in aid of metaphysic. More especially, no existing metaphysics could assist me in the least, because this deduction must prove the [10] very possibility of metaphysic. But as soon as I had succeeded in solving Hume's problem not merely in a particular case, but with respect to the whole faculty of pure reason, I could proceed safely, though slowly, to determine the whole sphere of pure reason completely and from general principles, in its bounds, as well as in its contents. This was what metaphysic required, in order to construct its system safely.

THE CRITIQUE OF PURE REASON

The Problem of the Critique

It is of very great advantage, to others, as well as to oneself, to be able to bring together various topics of investigation in a single problem. Now, the true problem of pure reason may be put in this way—How are *a priori* synthetic judgments possible?

Should this question be answered in a satisfactory way, we shall at the same time learn what part reason plays in the foundation and completion of those sciences which contain a theoretical *a priori* knowledge of objects. Thus we shall be able to answer the questions—How is pure mathematics possible? How is pure physics possible? As these sciences actually exist, we may fairly ask how they are possible; for that they must be possible is proved by the fact that they exist. But as no real progress has as yet been made in the construction of a system that realizes the essential aim of metaphysic, it cannot be said that metaphysic exists, and there is, therefore, reason to doubt whether it is possible at all.

Yet in one sense metaphysic may certainly be said to exist, namely, in the sense that there is in man a natural disposition to seek for this kind of knowledge. But as all attempts to answer the questions which human reason is naturally impelled to ask, as, for instance, whether the world had a beginning, or has existed from all eternity, have always and unavoidably ended in self-contradiction; we cannot be satisfied with asserting the mere natural disposition to metaphysical speculation, or, in other words, with the bare ability of pure reason to construct some sort of metaphysic. It must be possible for reason to attain to certainty one way or the other: we must be able to ascertain whether reason can know the objects it seeks, or whether it cannot know them; we must find a conclusive answer to the question whether pure reason is capable or incapable of determining the nature of those objects, and whether, therefore, its domain may with confidence be enlarged beyond the limits of experience, or must be restricted within them. Accordingly, the third and last question, which flows from the general problem of pure reason, may be correctly put in this way: How is a science of metaphysic possible? Thus a criticism of reason in the end necessarily leads to science, whereas the dogmatic employment of reason without previous criticism can lead only to groundless assertions, to which other assertions equally specious may always be opposed, the inevitable result being scepticism.

From all that has been said we get the idea of a unique science, which may be called the Critique of Pure Reason. It is not a doctrine, but a criticism of pure reason, and its speculative value is entirely negative, because it does not enlarge our knowledge, but only casts light upon the nature of our reason and enables us to keep it free from error. By transcendental knowledge I mean all knowledge that is occupied, not with objects, but with the way in which a knowledge of objects may be gained, so far as that is possible *a priori*. What we propose is not a doctrine of pure reason, but a transcendental criticism, the purpose of which is not to extend knowledge, but to rectify it, and to supply a touchstone of the value of all *a priori* knowledge.

This transcendental criticism will afford a complete architectonic plan of transcendental philosophy, as exhibited in its principles, and will therefore give a perfect guarantee of the completeness and stability of the edifice in all its parts.

The Critique of Pure Reason therefore contains all that is essential to the idea of transcendental philosophy, and if we distinguish it from that philosophy, the reason is that it does not carry its analysis beyond what is required in a complete estimate of *a priori* synthetic knowledge.

The main thing to be kept in view in the division of such a science is that no ideas be allowed to enter that are in any way of empirical origin, or, in other words, that it consist only of perfectly pure *a priori* knowledge. Hence, although the principles and fundamental conceptions of morality are *a priori*, they form no part of a transcendental philosophy, because they are necessarily relative to the conceptions of pleasure and pain, desire and inclination, etc., which in their origin are empirical.

In a systematic division of this science we must have, firstly, a doctrine of the elements; secondly, a doctrine of the method of pure reason. As to the subdivisions, it seems enough to say at present that there are two stems of human knowledge—Sensibility and Understanding, which may perhaps spring from a common root, unknown to us, and that by the one objects are given, by the other they are thought. Now, if Sensibility is found to contain an *a priori* element, without which objects could not be given to us, an investigation into the nature of that element will be one of the tasks of transcendental philosophy. The doctrine of this transcendental element of sensible perception will form the first part of the science of elements, because we must consider the conditions under which objects of human knowledge are given, before we go on to inquire into the conditions under which they are thought.

—TRANSLATION OF MAHAFFY AND BERNARD.

TRANSCENDENTAL AESTHETIC

Sensation is the actual affection of our sensibility, or capacity of receiving impressions, by an object. The perception which refers to an object through sensation, is empirical perception. The undetermined object of such a perception is a phenomenon (Erscheinung).

That element in the phenomenon which corresponds to sensation I call the matter, while that element which makes it possible that the various determinations of the phenomenon should be arranged in certain ways relatively to one another, is its form. Now, sensations cannot possibly give order or form to themselves. The matter of a phenomenon is given to us entirely *a posteriori*, but its form must lie *a priori* in the mind, ready to be applied to all sensations as they arise, and hence it must be capable of being considered by itself apart from sensation.

This pure form of sensibility is also called pure perception. Thus, if from the consciousness of a body, I separate all that the understanding has thought into it, as substance, force, divisibility, etc., and all that is due to sensation, as impenetrability, hardness, colour, etc.; what is left over are extension and figure. These, therefore, belong to pure perception, which exists in the mind *a priori*, as a mere form of sensibility, even when no sensation or object of sense is actually present.

The science of all the *a priori* principles of sensibility I call Transcendental Æsthetic, in contradistinction from the science of the principles of pure thought, which I call Transcendental Logic.

In Transcendental Æsthetic we shall first of all isolate sensibility, abstracting from all that the understanding contributes through its conceptions, so that we may have nothing before us but empirical perception. In the next place, we shall separate from empirical perception all that belongs to sensation; when there will remain only pure perception, or the mere form of phenomena, the sole element that sensibility can yield *a priori*. If this is done, it will be found that there are two pure forms of sensible perception, which constitute principles of *a priori* knowledge, namely, Space and Time. With these it will now be our business to deal.

SECTION I. SPACE

B. *Metaphysical Exposition of Space.*

In external sense we are conscious of objects as outside of ourselves, and as all without exception in space. In space their shape, size, and relative position are marked out, or are capable of being marked out. Inner sense, in which we are conscious of ourselves, or rather of our own state, gives us, it is true, no direct perception of the soul itself as an object; but it nevertheless is the one single form in which our own state comes before us as a definite object of perception; and hence all inner determinations appear to us as related to one another in time. We cannot be conscious of time as external, any more than we can be conscious of space as something within us. What then, are space and time? Are they in themselves real things? Are they only determinations, or perhaps merely relations of things which yet would belong to things in themselves even if those things were not perceived by us? Or, finally, have space and time no meaning except as forms of perception, belonging to the subjective constitution of our own mind, apart from which they cannot be predicated of anything whatever? To answer these questions I shall begin with a metaphysical exposition of space. An exposition I call it, because it gives a distinct although not a detailed, statement of what is implied in the idea of space; and the exposition is metaphysical, because it brings forward the reasons we have for regarding space as given *a priori*.

(1) Space is not an empirical conception, which has been derived from external experiences. For I could not be conscious that certain of my sensations are relative to something outside of me, that is, to something in a different part of space from that in which I myself am; nor could I be conscious of them as outside of and beside one another, were I not at the same time conscious that they not only are different in content, but are in different places. The consciousness of space is, therefore, necessarily presupposed in external perception. No experience of the external relations of sensible things could yield the idea of space, because without the consciousness of space there would be no external experience whatever.

(2) Space is a necessary *a priori* idea, which is presupposed in all external perceptions. By no effort can we think space to be away, although we can quite readily think of space as empty of objects. Space we therefore regard as a condition of the possibility of phenomena and not as a determination dependent on phenomena. It is thus *a priori*, and is necessarily presupposed in external phenomena.

(3) Space is not a discursive or general conception of the relations of things, but a pure perception. For we can be conscious only of a single space. It is true that we speak as if there were many spaces, but we really mean only parts of one and the same identical space. Nor can we say that these parts exist before the one all-embracing space, and are put together to form a whole; but we can think of them only as in it. Space is essentially single; by the plurality of spaces we merely mean that because space can be limited in many ways, the general conception of spaces presupposes such limitations as its foundation. From this it follows, that an *a priori* perception, and not an empirical perception, underlies all conceptions of pure space. Accordingly, no geometrical proposition, as, for instance, that any two sides of a triangle are greater than the third side, can ever be derived from the general conceptions of line and triangle, but only from perception. From the perception, however, it can be derived *a priori*, and with demonstrative certainty.

(4) Space is presented before our consciousness as an infinite magnitude. Now, in every conception we certainly think of a certain attribute as common to an infinite number of possible objects, which are subsumed under the conception; but, from its very nature, no conception can possibly be supposed to contain an infinite number of determinations within it. But it is just in this way that space is thought of, all its parts being conceived to exist *ad infinitum*. Hence the original consciousness of space is an *a priori* perception, not a conception.

c. *Transcendental Exposition of Space*

A transcendental exposition seeks to show how, from a certain principle, the possibility of other *a priori* synthetic knowledge may be explained. To be successful, it must prove (1) that there really are synthetic propositions which can be derived from the principle in question, (2) that they can be so derived only if a certain explanation of that principle is adopted.

Now, geometry is a science that determines the properties of space synthetically and yet *a priori*. What, then, must be the nature of space, in order that such knowledge of it may be possible? Our original consciousness of it must be perception, for no new truth, such as we have in the propositions of geometry, can be obtained from the mere analysis of a given conception (Introduction, 5). And this perception must be *a priori*, or, in other words, must be found in us before we actually observe an object, and hence it must be pure, not empirical perception. For all geometrical propositions, as, for instance, that space has but three dimensions, are of demonstrative certainty, or present themselves in consciousness as necessary; and such propositions cannot be empirical, nor can they be derived from judgments of experience (Introduction, 2).

How, then, can there be in the mind an external perception, which is antecedent to objects themselves, and in which the conception of those objects may be determined *a priori?* Manifestly, only if that perception has its seat in the subject, that is, if it belongs to the formal constitution of the subject, in virtue of which it is so affected by objects as to have a direct consciousness or perception of them; therefore, only if perception is the universal form of outer sense.

Our explanation is, therefore, the only one that makes the possibility of geometry intelligible, as a mode of *a priori* synthetic knowledge. All other explanations fail to do so, and, although they may have an external resemblance to ours, may readily be distinguished from it by this criterion.

Inferences

(*a*) Space is in no sense a property of things in themselves, nor is it a relation of things in themselves to one another. It is not a determination that still belongs to objects even when abstraction has been made from all the subjective conditions of perception. For we never could perceive *a priori* any determination of things, whether belonging to them individually or in relation to one another, antecedently to our perception of those things themselves.

(*b*) Space is nothing but the form of all the phenomena of outer sense. It is the subjective condition without which no external perception is possible for us. The receptivity of the subject, or its capability of being affected by objects, necessarily exists before there is any perception of objects. Hence it is easy to understand, how the form of all phenomena may exist in the mind *a priori*, antecedently to actual observation, and how, as a pure perception in which all objects must be determined, it may contain the principles that determine beforehand the relations of objects when they are met with in experience.

It is, therefore, purely from our human point of view that we speak of space, of extended things, etc. Suppose the objective conditions to be taken away, without which we cannot have any external perception, or be affected by objects, and the idea of space ceases to have any meaning. We cannot predicate spatial dimensions of things, except in so far as they appear in our consciousness. The unalterable form of this receptivity, which we call sensibility, is a necessary condition of all the relations in which objects are perceived as outside of us, and this form, when it is viewed in abstraction from objects, is the pure perception that is known by the name of space. We are not entitled to regard the conditions that are proper to our sensibility as conditions of the possibility of things, but only of things as they appear to us. Hence, while it is correct to say, that space embraces all things that are capable of appearing to us as external, we cannot say, that it embraces all things as they are in themselves, no matter what subject may perceive them, and, indeed, whether they are perceived or not. For we have no means of judging whether other thinking beings are in their perceptions bound down by the same conditions as ourselves, and which for us hold universally. If we state the limitations under which a judgment holds of a given subject, the judgment is then unconditionally true. The proposition that all things are side by side in space, is true only under the limitation that we are speaking of our own sensible perception. But if we more exactly define the subject of the proposition by saying, that all things as external phenomena are side by side in space, it will be true universally and without any exception. Our exposition, therefore, establishes the reality, or objective truth of space as a determination of every object that can possibly come before us as external; but at the same time it proves the ideality of space, when space is considered by reason relatively to things in themselves, that is, without regard to the constitution of our sensibility. We, therefore, affirm the empirical reality of space, as regards all possible external experience; but we also maintain its transcendental ideality, or, in other words, we hold that space is nothing at all, if its limitation to possible experience is ignored, and it is treated as a necessary condition of things in themselves.

SECTION II. TIME

D. *Metaphysical Exposition of Time*

(1) Time is not an empirical conception, which has been derived from any experience. For we should not observe things to co-exist or to follow one another, did we not possess the idea of time *a priori*. It is, therefore, only under the presupposition of time, that we can be conscious of certain things as existing at the same time (simultaneously), or at different times (successively).

(2) Time is a necessary idea, which is presupposed in all perceptions. We cannot be conscious of phenomena if time is taken away, although we can quite readily suppose phenomena to be absent from time. Time is, therefore, given *a priori*. No phenomenon can exist at all that is not in time. While, therefore, phenomena may be supposed to vanish completely out of time, time itself, as the universal condition of their possibility, cannot be supposed away.

(3) Time is not a discursive, or general conception, but a pure form of sensible perception. Different times are but parts of the very same time. Now, the consciousness of that which is presented as one single object, is perception. Moreover, the proposition, that no two moments of time can co-exist, cannot be derived from a general conception. The proposition is synthetic, and cannot originate in mere conceptions. It therefore rests upon the direct perception and idea of time.

(4) The infinity of time simply means, that every definite quantity

of time is possible only as a limitation of one single time. There must, therefore, be originally a consciousness of time as unlimited. Now, if an object presents itself as a whole, so that its parts and every quantity of it can be represented only by limiting that whole, such an object cannot be given in conception, for conceptions contain only partial determinations of a thing. A direct perception must therefore be the foundation of the idea of time.

E. *Transcendental Exposition of Time*

Apodictic principles which determine relations in time, or axioms of time in general, are possible only because time is the necessary *a priori* condition of all phenomena. Time has but one dimension; different times do not co-exist but follow one another, just as different spaces do not follow one another but co-exist. Such propositions cannot be derived from experience, which never yields strict universality or demontrative certainty. If they were based upon experience, we could say only, that it has ordinarily been observed to be so, not that it must be so. Principles like these have the force of rules, that lay down the conditions without which no experience whatever is possible; they are not learned from experience, but anticipate what experience must be.

Let me add here that change, including motion or change of place, is conceivable only in and through the idea of time. Were time not an inner *a priori* perception, we could not form the least idea how there should be any such thing as change. Take away time, and change combines in itself absolutely contradictory predicates. Motion, or change of place, for instance, must then be thought of as at once the existence and the non-existence of one and the same thing in the same place. The contradiction disappears, only when it is seen that the thing has those opposite determinations one after the other. One conception of time as an *a priori* form of perception, therefore explains the possibility of the whole body of *a priori* synthetic propositions in regard to motion that are contained in the pure part of physics, and hence it is not a little fruitful in results.

F. *Inferences*

(a) Time is not an independent substance nor an objective determination of things, and hence it does not survive when abstraction has been made from all the subjective conditions of perception. Were it an independent thing, it would be real without being a real object of consciousness. Were it a determination or order of things as they are in themselves, it could not precede our perception of those things as its necessary condition, nor could it be known by means of synthetc judgments. But the possibility of such judgments becomes at once intelligible if time is nothing but the subjective condition, without which we can have no perception whatever. For in that case we may be conscious of this form of inner perception before we are conscious of objects, and therefore *a priori*.

(*b*) Time is nothing but the form of inner sense, that is, of the perception of ourselves and our own inner state. As it has no influence on the shape or position of an object, time cannot be a determination of outer phenomena as such; what it does determine is the relation of ideas in our own inner state. And just because this inner perception has no shape of its own, we seek to make up for this want by analogies drawn from space. Thus, we figure the series of time as a line that proceeds to infinity, the parts of which form a series; and we reason from the properties of this line to all the properties of time, taking care to allow for the one point of difference, that the parts of the spatial line all exist at once, while the parts of the temporal line all follow one after the other. Even from this fact alone, that all the relations of time may thus be presented in an external perception, it would be evident that time is itself a perception.

(*c*) Time is the formal *a priori* condition of all phenomena without exception. Space, as the pure form of all external phenomena, is the *a priori* condition only of external phenomena. But all objects of perception, external as well as internal, are determinations of the mind, and, from that point of view, belong to our inner state. And as this inner state comes under time, which is the formal condition of inner perception, time is an *a priori* condition of all phenomena: it is the immediate condition of inner phenomena, and so the mediate condition of outer phenomena. Just as I can say, *a priori*, that all external phenomena are in space, and are determined *a priori* in conformity with the relations of space, so, from the principle of the inner sense, I can say quite generally that all phenomena are in time, and stand necessarily in relations of time.

If we abstract from the manner in which we immediately perceive our own inner state, and mediately all external phenomena, and think of objects in themselves, we find that in relation to them time is nothing at all. It is objectively true in relation to phenomena, because we are conscious of phenomena as objects of our senses; but it is no longer objective, if we abstract from our sensibility, and therefore from the form proper to our perceptive consciousness, and speak of things as such. Time is therefore a purely subjective condition of human perception, and in itself, or apart from the subject, it is nothing at all. Nevertheless, it is necessarily objective in relation to all phenomena, and therefore also to everything that can possibly enter into our experience. We cannot say that all things are in time, because when we speak of things in this unqualified way, we are thinking of things in abstraction from the manner in which we perceive them, and therefore in abstraction from the condition under which alone we can say that they are in time. But, if we qualify our assertion by adding that condition, and say that all things as phenomena, or objects of sensible perception, are in time, the proposition is, in the strictest sense of the word, objective, and is universally true *a priori*.

We see, then, that time is empirically real, or is objectively true in relation to all objects that are capable of being presented to our senses. And as our perception always is sensuous, no object can ever be presented to us in experience which does not conform to time as its condition. On the other hand, we deny to time all claim to absolute reality, because such a claim, in paying no heed to the form of sensible perception, assumes time to be an absolute condition or property of things. Such properties, as supposed to belong to things in themselves, can never be presented to us in sense. From this we infer the transcendental ideality of time; by which we mean that, in abstraction from the subjective conditions of sensible perception, time is simply nothing, and cannot be said either to subsist by itself, or to inhere in things that do subsist.

G. *Explanatory Remarks*

To this doctrine, which admits the empirical reality of time, but denies its absolute or transcendental reality, there is one objection so commonly made, that I must suppose it to occur spontaneously to everybody who is new to the present line of thought. It runs thus: No one can doubt that there are real changes, for, even if it is denied that we perceive the external world, together with the changes in it, we are at least conscious of a change in our own ideas. Now, changes can take place only in time. Therefore time is real.

There is no difficulty in meeting this objection. I admit all that is said. Certainly time is real; it is the real form of inner perception. It has reality for me relatively to my inner experience; in other words, I actually am conscious of time and of my own determinations as in it.

Time is therefore real, not as an object beyond consciousness, but as the manner in which I exist for myself as an object of consciousness. But, if I could be perceived by myself or by any other being without the condition of sensibility, the very same determinations, which now appear as changes, would not be known as in time, and therefore would not be known as changes. The empirical reality of time thus remains, on our theory, the condition of all our experience. It is only its absolute reality that we refuse to admit. Time is therefore nothing but the form of our inner perception. If we take away from it the peculiar condition of our sensibility, the idea of time also vanishes; for time does not belong to objects as they are in themselves, but only to the subject that perceives them.

Time and space are two sources of knowledge from which a variety of *a priori* synthetic judgments may be derived. Mathematics, especially, supplies a splendid instance of such judgments, in the science of space and the relations of space. Time and space are the two pure forms of all sensible perception, and as such they make *a priori* synthetic propositions possible. And just because they are mere conditions of sensibility, they mark out their own limits as sources of *a priori* knowledge. Applying only to objects regarded as phenomena, they do not present things as they are in themselves. Beyond the phenomenal world, which is their legitimate domain, they cannot be employed in determination of objects. But this limitation in no way lessens the stability of our empirical knowledge; for, such knowledge, as depending upon necessary forms of the perceptions of things, is just as certain as if it rested upon necessary forms of things in themselves.

Transcendental Æsthetic cannot contain more than these two elements. This is plain, if we reflect that all other conceptions belonging to sensibility presuppose something empirical. Even the idea of motion, in which both elements are united, presupposes the observation of something that moves. Now, there is nothing movable in space considered purely by itself; hence that which is movable can be found in space only by experience, and is therefore an empirical datum. Similarly the idea of change cannot be put among the *a priori* data of transcendental æsthetic. Time itself does not change, but only something that is in time; hence the idea of change must be derived from the observation of some actual object with its successive determinations—that is, from experience.

H. *General Remarks on the Transcendental Æsthetic*

(1) A distinction is commonly drawn between what belongs essentially to an object, and is perceived by every one to belong to it, and what is accidental, being perceived only from a certain position, or when a special organ is affected in a particular way. In the one case, we are said to know the object as it is in itself; in the other case, to know it only as it appears to us. This, however, is merely an empirical distinction. For, it must be remembered, that the empirical object which is here called the thing, is itself but an appearance. If this were all, our transcendental distinction would be altogether lost sight of, and we might imagine ourselves to know things in themselves when we knew only phenomena. For the truth is, that, however far we may carry our investigations into the world of sense, we never can come into contact with aught but appearances. For instance, we call the rainbow in a sun-shower a mere appearance, and the rain the thing itself. Nor is there any objection to this, if we mean to state merely the physical truth, that from whatever position it is viewed the rain will appear to our senses as a real object of experience. But, if we go beyond the fact, that the sensible object is here the same for every one, and ask whether the object is known as it is in itself, we pass to the transcendental point of view, and the question now is in regard to the relation of our consciousness of the object to the object as it exists apart from our consciousness. In this point of view, not merely the rain-drops, but their round shape, and even the space in which they fall, must be regarded as mere appearances, not as things in themselves. Every aspect of the phenomenon, in short, is but a modification or a permanent form of our sensible perception, while the transcendental object remains to us unknown.

(2) It is recognized in natural theology, not only that God cannot be an object of perception to us, but that He can never be an object of sensuous perception to Himself. At the same time, His knowledge must be perception, and not thought, for thought always involves limitations. Now, the natural theologian is very careful to say, that God, in His perception, is free from the limits of space and time. But, how can this possibly be maintained, if it has previously been assumed, that space and time are forms of things in themselves? It must then be held that, even if those things were annihilated, space and time would continue to be *a priori* conditions of their existence. And if they are conditions of all existence, they must be conditions of the existence even of

God. We can avoid this conclusion only by saying that space and time are not objective forms of all things, but subjective forms of our outer as well as of our inner perceptions. In fact our perception is sensuous, just because it is not original. Were it original, the very existence of the object would be given in the perception, and such a perception, so far as we can see, can belong only to the Original Being. Our perception is dependent upon the existence of the object, and therefore it is possible only if our perceptive consciousness is affected by the presence of the object.

Nor is it necessary to say, that man is the only being who perceives objects under the forms of space and time; it may be that all finite thinking beings agree with man in that respect, although of this we cannot be certain. But, however universal this mode of perception may be, it cannot be other than sensuous, simply because it is derivative (*intuitus derivativus*) and not original (*intuitus originarius*), and therefore is not an intellectual perception. An intellectual perception, as we have already seen reason to believe, is the prerogative of the Original Being, and never can belong to a being which is dependent in its existence as well as in its perception, and in fact is conscious of its own existence only in relation to given objects.

Conclusion of the Transcendental Æsthetic

We have then, in the Transcendental Æsthetic, one of the elements required in the solution of the general problem of transcendental philosophy: How are *a priori* synthetic propositions possible? Such propositions rest upon space and time, which are pure *a priori* perceptions. To enable us to go beyond a given conception, in an *a priori* judgment, we have found that something is needed, which is not contained in the conception, but in the perception corresponding to it, something therefore that may be connected with that conception synthetically. But such judgments, as based upon perception, can never extend beyond objects of sense, and therefore hold true only for objects of possible experience.

TRANSCENDENTAL LOGIC

1. *General Logic*

There are two ultimate sources from which knowledge comes to us: either we receive ideas in the form of impressions, or, by our spontaneous faculty of conception, we know an object by means of those ideas. In the former case, the object is given to us; in the latter case, it is thought in relation to the impressions that arise in our consciousness.

Perception and conception, therefore, are the two elements that enter into all our knowledge. To every conception some form of perception corresponds, and no perception yields knowledge without conception. Both may be either pure or empirical; empirical, if sensation, which occurs only in the actual presence of an object, is implied; pure, if there is no intermixture of sensation. We may call sensation the matter of sensuous knowledge. Hence pure perception contains only the form under which a definite object is perceived, and pure conception the form in which an object in general is thought. Pure perceptions or pure conceptions alone are possible *a priori*, while empirical perceptions or empirical conceptions are possible only *a posteriori*.

If sensibility is the receptivity of the mind in the actual apprehension of some impression, understanding is the spontaneity of knowledge, or the faculty that of itself produces ideas. We are so constituted that our perception always is sensuous; or it shows merely the manner in which we are affected by objects. But, we have also understanding, or the faculty of thinking the object of sensuous perception. Neither of these is to be regarded as superior to the other. Without sensibility no object would be given to us, without understanding none would be thought. Thoughts without content are empty, perceptions without conceptions are blind. It is therefore just as necessary to make our conceptions sensuous, that is, to add the object to them in perception, as it is to make our perceptions intelligible, that is, to bring them under conceptions. Neither of these faculties or capacities can do the work of the other. Understanding can perceive nothing, the senses can think nothing. Knowledge arises only from their united action. But this is no reason for confusing the function of either with that of the other; it is rather a strong reason for carefully separating and distinguishing the one from the other. Hence it is, that we distinguish Æsthetic, as the science of the universal rules of sensibility, from Logic, which is the science of the universal rules of understanding.

General logic, as distinguished from the special logic or organon of a particular science, is either pure or applied; but only the former is in the strict sense a science. There are two rules that must ever be kept in mind in pure general logic. (1) As general logic, it abstracts from all content of thought, and from all distinction of objects, and deals only with the pure form of thought. (2) As pure logic, it has no empirical principles. Psychology has no influence on the canon of the understanding, and therefore it does not, as has sometimes been supposed, contribute anything to pure logic. Logic is a demonstrative science, and whatever it contains must be certain entirely *a priori*

2. *Transcendental Logic.*

Pure general logic, then, abstracts from all the content of knowledge, or what is the same thing, from all relation of knowledge to its objects, and considers merely the logical form implied in the relation of one element of knowledge to another, or the universal form of thought. Now, we have learned from the Transcendental Æsthetic that there are pure as well as empirical perceptions, and it may well be, that a similar distinction obtains between the pure and the empirical thought of objects. In that case, there will be a logic that does not abstract from all the content of knowledge. Containing merely the rules of the pure thought of an object, it will exclude all knowledge, the content of which is empirical. It will also refer our knowledge of objects to its origin, in so far as that origin cannot be ascribed to objects themselves.

Let us suppose, then, that there are conceptions which relate to objects *a priori*, but which, as mere functions of pure thought, stand to objects in quite a different relation from that in which perceptions stand to them, whether these are pure or sensuous. As these conceptions will be of neither empirical nor æsthetic origin, we get the idea of a science of pure understanding and pure reason, the aim of which is to examine into the knowledge which we obtain by thinking objects completely *a priori*. Such a science, as setting forth the origin, the limits, and the objective validity of pure conceptions, we must call Transcendental Logic.

3. *Division of General Logic into Analytic and Dialectic*

General logic analyzes the whole formal procedure of understanding and reason into its elements, and presents these as principles by which the logical validity of knowledge may be estimated. This part of logic, which is well called Analytic, supplies a negative touchstone of truth . . . but it does not enable us to determine positively anything in regard to objects. At the same time, there is something so seductive in an art that enables us to reduce all our knowledge to the form of understanding, however empty and poor in content it may be, that general logic, although it is merely a canon of judgment, is apt to be used as an organon by means of which new truth, or rather the specious appearance of new truth, may be obtained. When it is thus misused as a supposed organon, logic is called Dialectic.

4. *Division of Transcendental Logic into Analytic and Dialectic*

Just as in Transcendental Æsthetic we isolated the sensibility, so in Transcendental Logic we shall isolate the understanding, and throw into relief that element in our knowledge which has its origin in the understanding alone. This pure element can be employed in actual knowledge, only on condition that objects are presented in perception to which it may be applied. For, without perception, the pure element of knowledge has no object, and therefore remains perfectly empty. That part of Transcendental Logic which sets forth the pure element in knowledge that belongs to understanding, and the principles without which no object whatever can be thought, is Transcendental Analytic. It is a logic of truth, because no knowledge can contradict it without losing all content, that is, all relation to an object, and therefore all truth. But there is a very seductive and deceptive tendency to employ that pure knowledge of understanding and those principles by themselves, and to apply them even beyond the limits of experience. Only in experience, however, can any matter or object be found to which the pure conceptions of understanding may be applied. There is thus a danger that understanding, with a mere show of rationality, may make a material use of its purely formal principles, and pass judgments upon all objects without distinction, whether they are given to us or not, and perhaps even although they cannot be given to us at all. That which is merely a canon for the criticism of understanding in its empirical use, is misused, when it is supposed to be an organon that may be employed universally and without restriction, and when it permits understanding to venture upon synthetic judgments about objects in general, and to pronounce and decide upon them. Pure understanding is then employed dialectically. The second part of Transcendental Logic must therefore consist of a criticism of dialectical illusion. It is called Dialectic, not because it is an art of producing illusion dogmatically—a favourite art of too many metaphysical jugglers—but because it is a criticism of understanding and reason in their hyperphysical use; a criticism, the aim of which is to expose their specious and groundless pretensions to the discovery and extension of knowledge through purely transcendental principles, and to preserve understanding from all sophistical illusion.

TRANSCENDENTAL ANALYTIC

CHAPTER I.—GUIDING THREAD FOR THE DISCOVERY OF THE CATEGORIES

The first part of Transcendental Analytic deals with the conceptions, the second part with the judgments of pure understanding.

It is the privilege as well as the duty of transcendental philosophy, to proceed in the search for its conceptions upon a definite principle; for these conceptions spring from the understanding pure and unmixed, and must therefore be connected together in the unity of a single conception or idea. This one fundamental conception is a systematic principle, by the application of which we may be certain *a priori* that we have found out all the pure conceptions of understanding, and have assigned to each its proper place in the whole system.

Section I.—The Logical Use of Understanding

Understanding has already been defined, negatively, as a non-sensuous faculty of knowledge. Now, as without sensibility we can have no perception, understanding cannot be a faculty of perception. But, apart from perception, the only other mode of obtaining knowledge is by means of conceptions. Therefore the knowledge that is due to understanding, or at least to human understanding, is a knowledge by means of conceptions; it is not perceptive, but discursive. All perceptions, as sensuous, rest upon affections, whereas conceptions rest upon functions. By function I mean the unity of act, in which various ideas are brought under a common idea. Conceptions are based upon the spontaneity of thought, sensuous perceptions on the receptivity of impressions. Now, the only use that understanding can make of these perceptions is to judge by means of them. And, as without perception there is no direct consciousness of an object, a conception is never related directly to an object, but always indirectly, through a perception or through another conception. Judgment is therefore the indirect knowledge of an object, or the knowledge of knowledge. In every judgment there is a conception which holds true of various ideas, and, among others, of one which is directly referred to an object. Thus, in the judgment that all bodies are divisible, the conception of divisibility applies to various other conceptions, but it is in an especial way related to the conception of body, as this again is related to certain objects that we directly perceive. Of these objects we are therefore conscious only indirectly in the conception of divisibility. Accordingly, all judgments are functions of unity, because they do not consist in the direct knowledge of an object, but bring that and other knowledge under the unity of a higher and more comprehensive conception. And as we can reduce all acts of understanding to judgments, understanding itself may be said to be a faculty of judgment. For, as we have seen above, understanding is the faculty of thought. To think is to know by means of conceptions. But conceptions, as predicates of possible judgments, are relative to the idea of an object not yet determined. By the conception of body is meant something—metal, for instance—which may be known by means of that conception. Body is a conception, just because it contains under it other determinations by means of which it may be referred to actual objects. It is thus the predicate of a possible judgment, such as, that every metal is a body. We may, therefore, find out all the possible functions of judgment if we can but tell what are all the possible functions of unity in judgment. And this, as we shall see in the next section, can quite readily be done.

Section II.—9. *The Logical Function of Understanding in Judgment.*

If we abstract from all the content of a judgment, and only pay heed to the mere form of understanding, we find that the functions of thought in judgment may be brought under four heads, each of which contains three subdivisions. Thus we get the following table:—

1. *Quantity of Judgments.*
Universal.
Particular.
Singular.

2. *Quality.*
Affirmative.
Negative.
Infinite.

3. *Relation.*
Categorical.
Hypothetical.
Disjunctive.

4. *Modality.*
Problematic.
Assertoric.
Apodictic.

Section III.—10. *The Pure Conceptions of Understanding or Categories.*

General Logic, as has been said, abstracts from all the content of knowledge, and looks to some other source, whatever that may be, for the content that it is to transform by analysis into conceptions. Transcendental Logic, on the other hand, has lying before it a complex of *a priori* sensibility, which it receives from Transcendental Æsthetic; without this complex, as a material upon which to operate, the conceptions of pure understanding would be without content or perfectly empty. Now, space and time have not only themselves, as pure *a priori* perceptions, a complexity of content; but, as they are the conditions without which the mind could not be receptive of impressions, and therefore could not be conscious of objects, they must always affect our conception of objects. Conception, however, is due to the spontaneous activity of thought, and hence the complex content of pure perception must first be surveyed, taken up into thought and combined, before there can be any knowledge. This act I call synthesis.

By synthesis, in its most general sense, is meant the act of putting various ideas together and grasping their multiplicity in one consciousness. Such synthesis is pure, if the multiplicity is given, not empirically but *a priori*, as in the case of space and time. Now, before we can analyze any idea, we must first have the idea, and hence the content of a conception cannot originally come into consciousness by analysis. It is by synthesis of various elements, whether those elements are given empirically or *a priori*, that we first get knowledge. No doubt the synthesis may at first be crude and confused, and it may stand in need of analysis, but yet it is by synthesis that the various elements are gathered together and united in the knowledge of a certain concrete object. It is to synthesis, therefore, that we must first direct our attention, if we would learn the true origin of our knowledge.

Synthesis in general, as we shall afterwards see, is due solely to the operation of imagination, a blind but indispensable function of the soul, without which we should have no knowledge whatever, but of which we are seldom ever conscious. To bring this synthesis to conceptions is the function of understanding, and it is only by this operation of understanding that we obtain what can properly be called knowledge.

Pure synthesis, viewed in its most general aspect, is the pure conception of understanding. By this pure synthesis I understand that which rests upon a basis of *a priori* synthetic unity. Thus in arithmetical addition, as is readily seen in the case of larger numbers, the synthesis conforms to a conception, because it proceeds on a common basis of unity, as, for instance, the decade. By this conception the unity in the synthesis of a complex is made necessary.

By analysis various ideas are brought under a single conception, as is shown in general logic. But it belongs to transcendental logic to tell us how the pure synthesis of ideas is brought to conceptions. The first element that enters into the knowledge of all objects *a priori* is the complex content of pure perception. The second element is the synthesis of this content by imagination. But as even this is not enough to constitute knowledge, a third element is supplied by understanding, in the conceptions which give unity to this pure synthesis, and which consist solely in the consciousness of this necessary synthetic unity.

The same function which gives unity to various ideas in a judgment also gives unity to the mere synthesis of various ideas in a perception; and this synthesis, in its most general expression, is the pure conception of understanding. Understanding at once gives analytic unity to conceptions, and synthetic unity to the complex content of perception; and indeed the logical form of judgment presupposes and rests upon the very same acts of thought as those by which a transcendental content is given to the various determinations of our consciousness. Hence it is that the pure conceptions of understanding, as they are fitly called, apply to objects *a priori*, and therefore do not fall within the view of general logic.

In this way there arises exactly the same number of pure conceptions of understanding, applying *a priori* to all objects of perception, as there are logical functions of judgments in the preceding table; for those functions completely specify understanding, and give a perfect measure of its powers. We shall call the pure conceptions categories, after Aristotle, because our object is the same as his, although our method and results are widely different.

TABLE OF CATEGORIES

1. *Quantity.*
Unity.
Plurality.
Totality.

2. *Quality.*
Reality.
Negation
Limitation.

3. *Relation.*
Inherence and Subsistence (*substantia et accidens*)
Causality and Dependence (cause and effect).
Community (reciprocity between the active and the passive).

4. *Modality.*
Possibility - Impossibility.
Existence - Non-existence.
Necessity - Contingency.

This, then, is a list of all the primary pure conceptions of synthesis that understanding contains within itself *a priori*. Because it contains these pure conceptions, it is called pure understanding, and only by them can it understand anything in the complex content of perception, that is, think an object. The table has not been left to the uncertain suggestions of empirical induction, but has been drawn up systematically, on the basis of a single principle, namely, the faculty of judgment, or, what is the same thing, the faculty of thought.

The table of categories suggests some nice points, which, perhaps, might be found to have an important bearing on the scientific form of all knowledge of reason. (1) The four classes of categories naturally fall into two groups; those in the first group being concerned with objects of perception, pure as well as empirical, while those in the second group are concerned with the existence of those objects, as related either to one another or to understanding. The first may be called the mathematical, the second the dynamical categories. The former, as is obvious, have no correlates, the latter have correlates. This distinction must have some ground in the nature of understanding. (2) It is also suggestive that the number of categories in each class is three, because usually all *a priori* division must be by dichotomy. To this it must be added that the third category in each class arises from the union of the second category with the first. Thus totality or allness is just plurality regarded as unity, limitation is reality combined with negations, community is causality in which two substances mutually determine one another, and lastly, necessity is just existence given by mere possibility.

CHAPTER II.—DEDUCTION OF THE CATEGORIES

13. *Principles of a Transcendental Deduction.*

There is a distinction in law between the question of right (*quid juris*) and the question of fact (*quid facti*). Both must be proved, but proof of a right or claim is called its deduction. Now, among the variety of conceptions that make up the very mixed web of human knowledge, there are certain conceptions that put in a claim for use entirely *a priori*, and this claim of course stands in need of deduction. It is useless to refer to the fact of experience in justification of such a claim, but at the same time we must know how conceptions can possibly refer to objects of experience, although those objects have not been derived from experience. An explanation of the manner in which conceptions can relate *a priori* to objects, I call a transcendental deduction; and from it I distinguish an empirical deduction, which simply tells us how a conception has been acquired by experience and reflection on experience. The former proves our right to the use of a certain conception; the latter merely points out that as a matter of fact it has come into our possession in a certain way.

We had no difficulty in explaining how space and time, although they are themselves known *a priori*, are yet necessarily related to objects, and make possible a synthetic knowledge of objects which is independent of all experience. For, as it is only by means of these pure forms of sense that we can be conscious of an object in empirical perception, space and time are pure perceptions, which contain *a priori* the condition of the possibility of objects as phenomena, and therefore synthesis in them has objective validity.

The categories of understanding, on the other hand, are not conditions under which objects are given in perception; hence objects might certainly be presented to us, even if they were not necessarily related to functions of understanding, as their *a priori* condition. Here, therefore, a difficulty arises that we did not meet with in the field of sensibility. The difficulty is, how subjective conditions of thought should have objective validity, or, in other words, how they should be conditions without which no knowledge of objects would be possible. Take, for instance, the conception of cause. Here we have a peculiar sort of synthesis, in which something B is conceived as following upon something else quite different A, in conformity with a rule. It is hard to see why phenomena should be subject to such an *a priori* conception. Why should not the conception be perfectly empty, and without any phenomenal object corresponding to it?

We cannot avoid the toil of such investigations by saying that experience is perpetually giving us examples of such conformity to law on the part of phenomena, and that we are thus enabled to form an abstract conception of cause, and to be certain of its objective validity. The conception of cause cannot possibly originate in that way; and hence we must either show that it rests completely *a priori* upon understanding, or we must discard it altogether as a mere fiction of the brain. For the conception demands that something A should be of such a nature that something else B follows from it necessarily, and in conformity with an absolutely universal rule. No pure conception of understanding can be the product of empirical induction without a complete reversal of its nature and use.

The transcendental deduction of all *a priori* conceptions must therefore be guided by the principle, that these conceptions must be the *a priori* conditions of all possible experience. Conceptions which make experience possible are for that very reason necessary. An analysis of the experience in which they occur would not furnish a deduction of them, but merely an illustration of their use. Were they not the primary conditions of all the experience in which objects are known as phenomena, their relation to even a single object would be utterly incomprehensible.

Section II.—A Priori Conditions of Experience.

It would be quite a sufficient deduction of the categories, and justification of their objective application, to show that, apart from them, no object whatever is capable of being thought. But there are two reasons why a fuller deduction is advisable: firstly, because, in thinking an object, other faculties besides understanding, or the faculty of thought proper, come into play; and, secondly, because it has to be explained how understanding can possibly be a condition of the knowledge of real objects. We must, therefore, begin with a consideration of the primary activities of the subject that are essential in the constitution of experience; and these we must view, not in their empirical, but in their transcendental character.

If consciousness were broken up into a number of mutually repellant states, each isolated and separated from the rest, knowledge would never arise in us at all, for knowledge is a whole of related and connected elements. When, therefore, I call sensible perception a synopsis, in order to mark the complexity of its content, it must be remembered that in this synopsis a certain synthesis is implied, and that knowledge is possible only if spontaneity is combined with receptivity. This is the reason why we must say that in all knowledge there is a three-fold synthesis: firstly, the apprehension in perception of various ideas, or modifications of the mind; secondly, their reproduction in imagination; and, thirdly, their recognition in conception. These three forms of synthesis point to three sources of knowledge, which make understanding itself possible, and through it all experience as an empirical product of understanding.

1. *Synthesis of Apprehension in Perception.*

Whatever may be the origin of our ideas, whether they are due to the influence of external things or are produced by internal causes, whether as objects they have their source *a priori* or in experience, as modifications of the mind they must all belong to the inner sense. All knowledge is, therefore, at bottom subject to time as the formal condition of inner sense, and in time every part of it without exception must be ordered, connected, and brought into relation with every other part. This is a general remark, which must be kept in mind in the whole of our subsequent inquiry.

We should not be conscious of the various determinations that every perception contains within itself were we not, in the succession of our impressions, conscious of time. If each feeling were limited to a single moment, it would be an absolutely individual unit. In order that the various determinations of a perception, as, for instance, the parts of a line, should form a unity, it is necessary that they should be run over and held together by the mind. This act I call the synthesis of apprehension. It is apprehension, because it goes straight to perception; it is synthesis, because only by synthesis can the various elements of perception be united in one object of consciousness.

Now, this synthesis of apprehension must be employed *a priori* also, or in relation to determinations not given in sensible experience. Otherwise we should have no consciousness of space and time *a priori*, for these can be produced only by a synthesis of the various determinations that are presented by sensibility in its original receptivity. There is therefore a pure synthesis of apprehension.

2. *Synthesis of Reproduction in Imagination.*

There is an empirical law of the association of ideas. When any two ideas have followed, or accompanied each other, an association between them is at last formed, and they are so connected that, even when an object is not present, the mind passes from the one to the other in conformity with a fixed rule. But this law of reproduction presupposes that phenomena are themselves actually subject to such a rule, and that the various elements in these phenomena of which we are conscious should accompany or follow one another in accordance with certain rules. Or any other supposition our empirical imagination would have nothing to reproduce in any way conforming to its own nature, and would therefore lie hidden in the depths of the mind as a dead, and to us unknown faculty. Were cinnabar, for instance, sometimes red and sometimes black, sometimes light and sometimes heavy; or were the same name given at one time to this object, and at another time to that, without the least regard to any rule implied in the nature of the phenomena themselves, there could be no empirical synthesis of reproduction.

There must, therefore, be something which makes the reproduction of phenomena possible at all, something which is the *a priori* ground of a necessary synthetic unity. That this is so, we may at once see, if we reflect that phenomena are not things in themselves, but are merely the play of our own ideas, and therefore at bottom determinations of the inner sense. Now, if we can show that even our purest *a priori* perceptions can yield knowledge, only in so far as they involve such a combination as makes a thoroughgoing synthesis of reproduction possible, we may conclude that this synthesis of imagination, being prior to all experience, rests upon *a priori* principles. We must then assume a pure transcendental synthesis as the necessary condition of all experience, for experience is impossible unless phenomena are capable of being reproduced. Now, if I draw a line in thought, or think of the time from one day to another, or even think of a certain number, it is plain that I must be conscious of the various determinations one after the other. But if the earlier determinations—the prior parts of the line, the antecedent moments of time, the units as they arise one after the other—were to drop out of my consciousness, and could not be reproduced when I passed on to the later determinations, I should never be conscious of a whole; and hence not even the simplest and most elementary idea of space or time could arise in my consciousness.

The synthesis of reproduction is therefore inseparably bound up with the synthesis of apprehension. And as the synthesis of apprehension is the transcendental ground of the possibility of all knowledge—of pure *a priori* as well as empirical knowledge—the reproductive synthesis of imagination belongs to the transcendental functions of the mind, and may therefore be called the transcendental faculty of imagination.

3. *Synthesis of Recognition in Conceptions.*

Were I not conscious that what I think now is identical with what I thought a moment ago, all reproduction in the series of ideas would be useless. The idea reproduced at a given moment would be for me a perfectly new idea. There would be no identical consciousness bound up with the act of producing one idea after another; and as without such consciousness there could be for me no unity, I should never be conscious of the various members of the series as forming one whole. If, in counting, I should forget that the units lying before my mind had been added by me one after the other, I should not be aware that a sum was being produced or generated in the successive addition of unit to unit; and as the conception of the sum is simply the consciousness of this unity of synthesis, I should have no knowledge of the number.

At this point it is necessary to have a clear idea of what we mean by an object of consciousness. We have seen that a phenomenon is just a sensation of which we are conscious, and that no sensation can be said to exist by itself as an object outside of consciousness. What, then, do we mean when we speak of an object as corresponding to our knowledge, and therefore as distinct from it? It is easy to see that this object can be thought of only as something$=x$, for there is nothing beyond knowledge that we can set up as contrasted with knowledge, and yet as corresponding to it.

It is plain that in knowledge we have to do with nothing but the various determinations of our own consciousness; hence the object$=x$, which corresponds to these determinations, if it is supposed to be distinct from every object of consciousness, is for us nothing at all. The unity which the object demands can be only the formal unity of consciousness in the synthesis of its various determinations. In saying that we know the object, we mean that we have introduced synthetic unity into the various determinations of perception. But this is impossible, if the perception could not be produced by a function of synthesis, which, in conforming to a rule, makes the reproduction of those determinations *a priori* necessary, and renders possible a conception that unites them.

There can be no knowledge without a conception, however indefinite or obscure it may be, and a conception is in form always a universal that serves as a rule. The conception of body, for instance, as a unity of the various determinations thought in it, serves as a rule in our knowledge of external phenomena. Now, it is always a transcendental condition that lies at the foundation of that which is necessary. There must, therefore, be a transcendental ground of the unity of consciousness in the synthesis of the various determinations implied in every perception; and this ground must be necessary to the conception of any object whatever, and therefore to the conception of every object of experience. In no other way can there be any object for our perceptions; for the object is nothing but that something$=x$, the conception of which involves necessity of synthesis.

This original and transcendental condition is just transcendental apperception. The consciousness, in internal perception, of oneself as determined to certain states, is merely empirical, and is always changing. In the flux of inner phenomena there can be no unchanging or permanent self. This form of self-consciousness is usually called inner sense or empirical apperception. Now, from empirical data it is impossible to derive the conception of that which must necessarily be numerically identical. What we require, in explanation of such a transcendental presupposition, is a condition that precedes all experience, and makes it possible.

No knowledge whatever, no unity and connection of objects, is possible for us, apart from that unity of consciousness which is prior to all data of perception, and without relation to which no consciousness of objects is possible. This pure, original, unchangeable consciousness I call transcendental apperception. That this is the proper name for it is evident, were it only that even the purest objective unity, that of the *a priori* conceptions of space and time, is possible only in so far as perceptions are related to it. The numerical unity of this apperception is, therefore, just as much the *a priori* foundation of all conceptions as the various determinations of space and time are the *a priori* foundation of the perceptions of sense.

It is this transcendental unity of apperception which connects all the possible phenomena that can be gathered together in one experience, and subjects them to laws. There could be no such unity of consciousness were the mind not able to be conscious of the identity of function, by which it unites various phenomena in one knowledge. The original and necessary consciousness of the identity of oneself is at the same time the consciousness of a necessary unity in the synthesis of all phenomena according to conceptions. These conceptions are necessary rules, which not only make phenomena capable of reproduction, but determine perception as perception of an object, that is, bring it under a conception of something in which various determinations are necessarily connected together. It would be impossible for the mind to think of itself as identical in its various determinations, and indeed to think that identity *a priori*, if it did not hold the identity of its own act before its eyes, and if it did not, by subjecting to a transcendental unity all the synthesis of empirical apprehension, make the connection of the various determinations implied in that synthesis possible in accordance with *a priori* rules.

17. *The synthetic Unity of Apperception is the Supreme Principle of Understanding.*

In the Transcendental Æsthetic, we have seen that the supreme principle, without which perception in its relation to sensibility is impossible, is that all the determinations of perception should stand under the formal conditions of space and time. Now, the supreme principle, without which perception, in its relation to understanding is impossible, is, that all determinations of perception should stand under conditions of the original synthetic unity of apperception. Under the former stand all determinations of perception, in so far as they are given to us; under the latter, in so far as they must be capable of being combined in one consciousness. Apart from the synthetic unity of apperception, nothing can be thought or known, because the determinations given in perception, not having the act of apperception, "I think," in common, would not be comprehended in one self-consciousness.

Speaking quite generally, understanding is the faculty of knowledge. Knowledge consists in the consciousness of certain given determinations as related to an object. An object, again, is that, in the conception of which the various determinations of a given perception are united. Now, all unification of determinations requires unity of consciousness in the synthesis of the determinations. Hence, the unity of consciousness is absolutely necessary, to constitute the relation of determinations to an object, give them objective validity, and make them objects of knowledge; and on that unity therefore rests the very possibility of understanding.

The principle of the original synthetic unity of apperception, as being completely independent of all conditions of sensuous perception, is the supreme condition of the pure use of understanding, and upon this pure use rests the whole of its empirical use. Space, as the mere form of external sensuous perception, does not of itself yield any knowledge; it but supplies the various elements of *a priori* perception that are capable of becoming knowledge. To know anything spatial, as, for instance a line, I must draw it, and so produce by synthesis a definite combination of the given elements. Thus, the unity of the act of combination is at the same time the unity of the consciousness in which the line is thought, and only in this unity of consciousness is a determinate space known as an object. The synthetic unity of consciousness is, therefore, an objective condition of all knowledge. It is not merely a condition which I must observe in knowing an object, but it is a condition under which every perception must stand, before it can become an object for me at all. Without this synthesis, the various determinations would not be united in one consciousness.

Although it is thus proved, that the synthetic unity of consciousness is the condition of all thought, the unity of consciousness, as has been already said, is in itself an analytic proposition. For, it says only, that all the determinations of which I am conscious in a given perception must stand under the condition, which enables me to regard them as mine, or as related to my identical self, and so to comprehend them as synthetically combined in one apperception, through the "I think" expressed in all alike.

But this is not the principle of every possible understanding, but only of an understanding, through the pure apperception of which, in the consciousness "I am," no determinations are given. If we had an understanding, which, by its mere self-consciousness, presented to itself the manifold determinations of perception; an understanding, which, by its very consciousness of objects, should give rise to the existence of these objects; such an understanding would not require, for the unity of consciousness, a special act of synthesis of manifold determinations. But this act of synthesis is essential to human understanding, which thinks, but does not perceive. It is, indeed, the supreme principle of human understanding. Nor can we form the least conception of any other possible understanding, whether of one that itself perceives, or of one that is dependent upon sensibility for its perception, but not upon a sensibility that stands under the same conditions of space and time.

18. *Objective Unity of Self-consciousness.*

The transcendental unity of apperception is that unity through which all the determinations given in a perception are united in a conception of the object. It is, accordingly, called objective, and must be distinguished from the subjective unity of consciousness, which is a determination of the inner sense, through which the complex of perception is given empirically to be combined into an object. Whether I shall be empirically conscious of certain determinations as simultaneous, or as successive, depends upon circumstances, or empirical conditions. Hence, the empirical unity of consciousness, through the association of the elements of perception, is itself a phenomenon, and is perfectly contingent. But the pure form of perception in time, as merely perception in general, stands under the original unity of consciousness just because the various determinations given in it are necessarily related to an "I think." It therefore stands under that original unity by means of the pure synthesis of understanding, which is the *a priori* ground of the empirical synthesis. Only the original unity of apperception is objective; the empirical unity, with which we are not here concerned, and which besides is only derived from the other, under given conditions *in concreto*, is merely subjective. To one man, for instance, a certain word suggests one thing, to another a different thing. In what is empirical, the unity of consciousness does not hold necessarily and universally of that which is given.

19. *The Logical Form of all Judgments consists in the objective unity of the conceptions they contain.*

A judgment is simply the way in which given ideas are brought to the objective unity of apperception. This is the force of the copula "is," which just marks the distinction between the objective unity and the subjective unity of given ideas. It indicates their relation to the original apperception, and their necessary unity. This holds good even if the judgment is itself empirical and therefore contingent. I do not mean, that, in the proposition, "Bodies are heavy," the idea of heavy is necessarily connected with the idea of body in empirical perception, but that they are connected with each other in the synthesis of perceptions through the necessary unity of apperception. That is to say, the two ideas are connected with each other in conformity with the principles by which ideas are objectively determined and become knowledge. Now, those principles are all derived from the supreme principle of the transcendental unity of apperception. Through this principle alone, ideas are related in the way of judgment, and become objectively valid. Thus we get a sufficient test of the distinction between the relation of ideas in a judgment, and a relation of the same ideas that is only of subjective validity, as, for instance, a relation depending upon the laws of association. In the latter case, all that I could say would be, that if I lift a body, I have a sensation of weight, but not, that the body is heavy. To say that the body is heavy, means, that the two ideas of heavy and body are connected together in the object, whatever the state of the subject may be, and not merely that they are contiguous in my observation, repeat it as often as I please.

20. *All sensuous Perceptions stand under the Categories as conditions under which alone their various determinations can come together in one consciousness.*

The various determinations given in a sensuous perception stand under the original synthetic unity of apperception, because in no other way could there possibly be any unity of perception (17). But that act of understanding, by which the determinations given in consciousness, whether these are perceptions or conceptions, are brought under a single apperception, is the logical function of the judgment (19). Hence, all the elements given in an empirical perception are determined by one of the logical functions of judgment, and thus brought into one consciousness. But the categories are just the functions of judgment, in so far as these are applied in determination of the various elements of a given perception (13). Therefore, the various determinations in a given perception necessarily stand under the categories.

22. *The Category has no other application in Knowledge than to objects of Experience.*

To think an object is not the same thing as to know it. Knowledge involves two elements: firstly, the conception or category, by which an object in general is thought; secondly, the perception by which it is given. If no perception could be given, corresponding to the conception, I should no doubt be able to think an object so far as its form was concerned, but as there would be no object in which that form was realized, I could not possibly have knowledge of any actual thing. So far as I could know, there would be nothing, and could be nothing, to which my thought might be applied. Now, the Æsthetic has shown to us that all the perception that we can have is sensuous; hence the thought of an object in general, by means of a pure conception of understanding, can become knowledge, only by being brought into relation with objects of sense. Sensuous perception is either the pure perception of space and time, or the empirical perception of that which is directly presented through sensation as actually in space and time. By the determination of space and time themselves, we can obtain that *a priori* knowledge of objects which mathematics supplies. But this knowledge is only of the form of phenomena, and it is still doubtful if actual things must be perceived in this form. Mathematical conceptions, therefore, can be called knowledge, only if it is presupposed that there are actual things which cannot be presented to us except under the form of that pure sensuous perception. Now, things in space and time are given to us only through empirical observation, that is, in perceptions that are accompanied by sensation. Hence, the pure conceptions of understanding, even if they are applied to *a priori* perceptions, as in mathematics, do not yield a knowledge of things. Before there can be any knowledge, the pure perceptions, and the conceptions of understanding through the medium of pure perceptions, must be applied to empirical perceptions. The categories, therefore, give us no knowledge of actual things, even with the aid of perception, except in so far as they are capable of being applied to empirical perception. In other words, they are merely conditions of the possibility of empirical knowledge. Now, such knowledge is called experience. Hence the categories have a share in the knowledge of those things only, that are objects of possible experience.

The above proposition is of the greatest importance, for it marks out the limits of the pure conceptions of understanding in their application to objects, just as Transcendental Æsthetic marked out the limits of the pure forms of sensuous perception. Space and time are but the conditions under which objects that are relative to our senses are capable of being presented to us, and therefore they apply only within the limits of experience. Beyond those limits they have no meaning whatever, for they are only in the senses, and have no reality apart from them. The pure conceptions of understanding are free from this limitation, and extend to objects of perception of any kind, whether that perception is like or unlike ours, if only it is sensuous and not intellectual. But this extension of conception beyond our sensuous perception does not help us in the least. For, the conceptions are in that case quite empty, and we are therefore unable even to say that there are any objects corresponding to them. They are mere forms of thought without objective reality, for we have no perception at hand, and therefore no object, to which the synthetic unity of apperception, which is the sole content of those forms of thought, could be applied. Only our sensuous and empirical perception can give to them meaning and reality.

If I suppose an object of a non-sensuous perception to be given, I can, no doubt, think of it as having all the predicates implied in my presupposition. I can say that the object has none of the determinations proper to sensuous perception; that it is not extended or in space, that its duration is not time, that there is in it no change or succession of states in time, etc. But no real knowledge of an object is gained by merely indicating how it is not perceived, so long as I cannot tell what is the content of its perception. I cannot in that way understand even the possibility of an object to which my pure perception could apply, for I am unable to bring forward a perception corresponding to such an object, and can say only that my perception can never bring me into contact with it. But what most concerns us here, is that to a thing of that nature, not even a single category could be applied. I could not say, for instance, that such a thing is a substance, that is, a thing that can exist as subject, but never as mere predicate. For, how could I apply the conception of substance, when, in the absence of all empirical perception, I should not even know that anything corresponding to my idea could exist at all.—From Watson's Selections.

EIGHTEENTH CENTURY SCIENCE

THE SEVENTEENTH CENTURY had been made memorable in the sciences by the discoveries of Galileo and Kepler in astronomy, of Harvey, Leeuwenhoeck, Malpighi and Grew in biology, of Boyle in chemistry, and of Guericke, Newton, Huyghens and Roemer in physics. Thus astronomy was put upon a firm foundation and much was done for physics. The eighteenth century was to see in physics the opening up of the field of electricity, and the first beginning of the conception of heat in terms of motion; the foundation of modern chemistry and geology, and the development in astronomy of the nebular hypothesis of the growth of the universe.

The century opened (1701) with the first attempts in organic chemistry made by Boerhaave. He decomposed organic substances such as plants by sublimation and showed that the substances in the plants are taken up from the earth in which they grow after first being dissolved in the water that soaks down from the rains. He followed up these facts by showing that animals are made up of reorganized vegetable matter. His analyses were, of course, imperfect, because chemistry knew nothing as yet of even such elements as oxygen, hydrogen, nitrogen or carbon, the chief components of organisms. In fact, during the first half of the century, chemistry was retarded by the acceptance of Stahl's phlogiston theory, which was that burning is the release of an imaginary substance called phlogiston, supposed to exist in all things capable of combustion.

In botany the work of the century was mostly descriptive and systematizing by Linnæus.

Haller and Hunter made a beginning in comparative anatomy by trying to compare similar organs in different animals, and Buffon attempted to describe all the known animals of the globe.

In physics the latter half of the century opened with the demonstration of the identity of electricity with lightning by Franklin (1752). Hitherto electricity had been a plaything. Franklin showed that it is in reality a giant. In 1760 Black discovered latent heat and in 1765 Watt applied the principle to the construction of the first practical steam-engine. Galvani (in 1789) found electricity to be present in animals and noted its effects in contracting the muscles. Volta in 1792 discovered chemical electricity and invented his battery, or "voltaic pile," to produce it. Rumford by studying the effect of motion in producing heat gave the old caloric theory that heat is a substance a severe shock, and opened the way for the nineteenth century conception of the conservation of energy.

In the latter half of the century Hutton and Smith laid the first foundation in geology by studying the formation of the earth.

In astronomy the century ended with a theory of the development of the universe. Lagrange (1736-1813) and Laplace (1749-1827) worked out mathematically the oscillations in the solar system caused by the interaction of its parts and showed its stability. Herschel (1738-1822) discovered the planet Uranus in 1781; found pairs of stars revolving round each other, thus demonstrating that the law of gravitation holds not only in our solar system but in the universe; showed that our solar system seems to be moving in a mass toward the far-off constellation of Hercules, and pointed out that some star clusters seem to consist of dispersed "star-matter" or gases. On these foundations Laplace built his hypothesis of the development of the universe from original gases.

Meantime, toward the close of the century, chemistry had supplied the conception of such gases. In 1756 Black by pouring acidulated water on limestone discovered carbonic acid gas; in 1766 Cavendish obtained hydrogen by pouring sulphuric acid and water on zinc. In 1774 Priestley procured oxygen by heating mercuric oxide, and later (1784) Cavendish combined this new gas with hydrogen by means of an electric spark passed through the mixture and found that they made water. Lavoisier revolutionized chemistry (1778) by showing that all combustion is the effect of combination with oxygen, thus overthrowing the old phlogiston theory. Chemistry had begun to grasp the elements of matter, and was on the high road toward being an exact science.

BOERHAAVE

HERMAN BOERHAAVE was born near Leyden, December 31, 1668, and died Professor of Medicine and Botany at Leyden, September 23, 1738. In medicine he was the most representative man of his time, but he was something of an eclectic in his beliefs and stands for no great advance in the subject. In chemistry, as noted previously, he did a great deal toward starting the study of physiological chemistry by his investigations into the growth of plants as related to the substances absorbed from the soil.

PHYSIOLOGICAL CONCEPTIONS

In order to discover Truth in this manner by observation and reason, it is requisite we should fix on some principles whose certainty and effects are demonstrable to our senses, which may serve to explain the phenomena of natural bodies, and account for the accidents that arise in them; such only are those which are purely material in the human body, with mechanical and physical experiments; for we are not sensible of any other way of attaining to a true knowledge of the universal and particular affections of bodies.

Demonstration is an evident proof of some dubious proposition, so that nobody who admits the general principles, can deny their assent; these are purest in the mathematics, though there are many demonstrations no less evident in physic, especially those which are taken from anatomy. But there is no necessity for the principles of any art to be proved in that art, it is sufficient if their certainty is by any means demonstrated in other arts.

These ought to be first adjusted with distinction, clearness, and certainty; with distinction, which points out one being from any other; as if one was to define a circle to be a right line continued upon a point till one end meets again with the other; with clearness, which consists of simple notions or ideas, easily conceived by any man in his senses, as that two and two joined make four; with certainty, which cannot be denied by any reasonable person, or which must always appear true upon examination.

The universal laws of nature, or affections of all bodies, depend on mechanical and physical principles, upon which alone their actions are explicable; the same laws are also true in the human body, for its matter appears to be universally the same with that of all other bodies; so that what may be said to be true of all bodies, may be also affirmed true in our own. Thus, if one should affirm, that by the friction of two bodies would arise heat, the same will also be true upon the friction of solid parts in the human body. But then there are other principles not to be explained by these universal laws, but by some particular disposition in the certain body; these properties are called physical. But a physician ought to consider both the affections of bodies in general, as well as those only proper to the human body, that from a judicious comparison and just reasoning, he may never subject the human body to those laws only, to which the generality of, but not all, bodies are liable.

26. But as there are in the human body many other appearances not intelligible upon those principles, they therefore are not to be demonstrated and explained by such principles; if we would avoid error we must take a very different course for that purpose; this will readily appear to any one who considers and admits for true the following propositions, which are elsewhere demonstrated:

Such as memory, understanding, reason and the knowledge of past and future appearances; which are peculiar to the mind, a being without figure or extension, and conscious of pleasure and pain.

27. We are to consider (1) that Man is composed of a body and mind, united to each other; (2) that the nature of these are very different, and that therefore, (3) each has a life, actions and affections differing from the other; yet (4) that there is such a reciprocal connection and consent between the particular thoughts and affections of the mind and the body, that a change in one always produces a change in the other, and the reverse; also (5) that the mind performs some actions by mere thought, without any effect upon the body; and that it has other thoughts, which arise barely from some change in the condition of the body; on the other hand, also, (6) that there are some actions performed by the body without the attention, knowledge, or desire of the mind, which is neither concerned therein as the cause or effect of those actions; that there are also some ideas formed in the

mind of a person in health by its past actions; and, lastly, that there are other ideas compounded both of the past and present. That (7) whatever we observe to arise from thought in the human body, is to be only ascribed to the mind as the cause. But (8) that every appearance which has solidity, figure, or motion, is to be ascribed to the body and its motion for a principle, and ought to be demonstrated and explained by their properties. That (9) we cannot understand or explain the manner in which the body and mind reciprocally act upon each other from any consideration of their nature separate; we can only (10) remark by observation their effects upon each other, without explaining them, and when any difficulty or appearance has been traced so far, that it only remains to explain the manner of their reciprocal action, we are to suppose such account satisfactory, both because it may be sufficient for all the purposes of the physician, and as it is impossible for him to search any further.

By the body we understand that part of us which is extended in three dimensions, has a form, and is fitted for motion, or rest, etc.

By the mind we understand that being which thinks, and perceives itself thinking, and the thing thought of.

The union of the body and mind is such, that the mind cannot resist forming to itself the ideas of pleasure and pain, when the body is in a particular manner affected; nor can the healthy body refuse to obey the action of the mind under particular circumstances.

By the nature of the body or mind, we understand everything which we are satisfied belong to each. The essential nature of the mind is to be conscious, or to think; but to think of this and that particular thing, is accidental to it. The essential nature of the body is extension and resistance. These attributes have nothing in common to each other, nor ought one to conclude from similitude, that two beings are reducible to one general class. When I think of extension, it does not infer anything of thought; and when I reflect upon thought, I can perceive no connexion of it with extension; therefore the idea of the body has nothing in common with that of the mind, and the reverse. In the same manner, there is no connexion between the common ideas of time, sound, gravity, light, etc. Socrates made a proper answer to Crito, when he was asked in what place he should choose to be buried? viz. "You will not find Socrates when you prepare my tomb, nor shall I be sensible of what you then do for me." Nor are the reasons wanting to prove from the present condition of the mind, that it may live hereafter without any commerce with its body.

The incomparable mathematician Vietus, who first restored algebra to us, received the enemies' letters from the king, to expound their mystical signs; while he was studying to explain their meaning, he was taken up with the most profound meditation for three whole days and nights, insomuch that he was not sensible of what had been transacted without his knowledge, taking no more concern of his body, than if it had been long deserted as an enemy by his mind. In like manner, we find Archimedes in a consternation when he first was ordered to answer King Hiero concerning the mixed gold in the crown till at last lighting upon the experiment, i. e., going into the bath, he cried out victory. And in the same manner a Roman, who was in a deep consternation of ecstasy, being not at all terrified at the advances of the Syracutians in battle, made a great conquest without once breaking his lines.

The life of the body is, 1. To generate motion under particular circumstances, as the loadstone approaches to iron. 2. For its constituent parts to attract each other, from whence proceeds the resistance to the force of external bodies, or *vis inertia.* 3. To gravitate, or tend towards the center of its planet. And then, 4, comes the affections proper to particular bodies. The life of the mind is, 1. To perceive the appearances of all external objects, by the changes they make in the organs of sensation. 2. To judge or compare the nature of two ideas with each other, and then to deduce some consequences, as that they are of the same kind, or different; as we conclude from the notions of a circle and triangle, that a triangle is not a circle. 3. To will anything. In a word, the life of the mind is to be conscious. These are all the functions of the mind; for past actions are uncertain, and they may be all referred to the single act of its consciousness.

The action of the body is to communicate motion to other bodies; the passions of it is to receive some change in itself from another body or a mind. The action of the mind is volition, which everybody is acquainted with, but no one can explain. The passions of the mind are the changes it receives from external objects by the senses. Suppose the mind to be thinking of a circle, and in the interim a cannon to go off, it will lose the idea of a circle, and acquire that of sound; this is the sufferance of the mind, because it can neither retain the idea of a circle, nor resist that of sound. There are also some affections in the mind different from the preceding, such as violent passions, or involuntary convulsions, which the mind cannot resist, and the faculty by which it moves and determines the several parts of the human body, agreeable to its inclination.

We cannot understand why two principles, which have no agreement in power, should thus concur in the same functions, though there have been three hypotheses framed to explain the intercourse of the body and mind: the first is, by the physical influx, which supposes the thing thought of and the thought itself to be one and the same: which we shall hereafter demonstrate to be absurd, inasmuch as our mind is ignorant of its own nature. The second is the system of occasional causes; and the third supposes a harmony established by God, making it for an infallible rule, that determinate actions of the mind must be necessarily attended with corresponding motions in the body, and the contrary: and this last seems to be the truest opinion, but it leaves us equally in the dark with the other.

If any action is to be explained which is compounded both of the faculties of the mind as well as of the body, such as walking, pain, voluntary respiration, etc., a just account ought to be first given how far, and in what manner, the body is concerned in the action, and then also of the mind, if this can be done; it is enough, without diving into the manner of connexion between the different actions; the explication of the corporeal actions appertains to the physician, and those of the mind to the philosopher; but their connexion can be explained by no man. Ideas may be conceived to arise in bodies without any relation to a thinking mind, as the senses grow out in their growing; but motion is not explicable from the affections of the body, nor even from the properties of the mind; therefore ideas and motion are not accountable from the mind [illegible] that the voluntary motions of the muscles [illegible] from the [illegible] in the mind [illegible] thing [illegible] in the idea of motion which [illegible] affection of the mind. We call [illegible] agreement or relation between [illegible] here are [illegible] impossible [illegible] for the great business [illegible] means of restoring the health [illegible] through some change [illegible] others; there[illegible] and mind are appertaining to a physician, is to be rejected, among those which are useless to the art. The physician, who cures diseases of the body, is not solicitous about those of the mind; for when the first is set to rights, the latter will quickly return to its office. Thus when the eye is blinded with a cataract, the mind cannot perceive sensible objects by it, the aid of physic is therefore called in to couch the cataract, or depress the opaque crystalline lens; after which the rays of light finding free admission to the retina, the mind will be sensible of visible objects by it; and thus the business of physic will be done without the assistance of optics. When a person is in a delirium, or swoon, the physician cannot recall the mind, which has no relation to his business; but by applying vinegar, or other volatiles to the nose, he can restore the sick machine to its former motions, and then the mind will also exhibit its former actions, and this full as well as if he understood the manner of connexion between the actions of the body and those of the conscious mind.

LINNÆUS

Carl von Linne (Carolus Linnaeus) was born May 13 (o. s.), 1707, at Rashult in Smaland, Sweden. He showed interest in plants when only about four years old, and continued in this passion to the neglect of the then more valued scholastic studies. His clergyman father was about to take him from school, but Dr. Rothman averted the crisis by urging Carl's father to fit him for medicine. In 1727 Carl went to the university (at Lund) as the private pupil of his former preceptor Hoek. At Lund he found a friend in Stobæus.

In 1728 he changed over to Upsala, and was there brought to the verge of starvation before he found another patron in Celsius. In 1732 he explored Lapland at the expense of the Academy of Sciences. In 1735 Linnæus fell in love with the daughter of Dr. Moræus, and left Sweden to seek his fortune.

He showed his manuscripts of the "Systema Natura" to Gronovius, who was so taken with it as to publish it at his own expense. The new system of classification was based on the sex system in plants, and

Linnæus is one of the chief developers of the sex theory. After visiting many of the noted professors of Europe, Linnæus returned to Stockholm in 1738. In 1739 he married Sarah Moræus, and as he was the next year elected professor in Upsala, his life was henceforth uneventful and happy, devoted to his family and the extension of his system of botany. He died in 1778. He had found botany a chaos and left it a unity.

A DISSERTATION ON THE SEXES OF PLANTS

Although the earliest observers of nature could not possibly be ignorant of the sexes of plants, it has been left for the philosophers of the present age to demonstrate them. And so abundant are the proofs of this phenomenon that not a single vegetable can be found which does not offer them to our consideration.

The Atabaians, from time immemorial, have derived their principal sustenance from the Phœnix, or Date-bearing Palm, the Persians from the Turpentine Tree, and the inhabitants of the Archipelago from the Fig, the people of Chios have likewise cultivated Mastich from the most remote ages. As it has all along been the practice of these nations to promote the action of the male trees on the female by the same means which they use at this day, they must certainly have been acquainted with the sexual difference in plants, upon which the success of this practice depends. It is altogether impossible that they should have been ignorant of a circumstance, which, in these trees at least is so apparent. If, however, we duly consider the fate of botanical science, we shall soon see why the doctrine in question has not been long ago universally understood and received.

The writings of the ancients show that botany had by no means made great progress among them, at the time when mathematics and astronomy had risen to a very high degree of perfection. The works of Theophrastus, Dioscorides, and Pliny, those repositories of ancient learning, have no pretensions to philosophy in this kind of study, notwithstanding the assiduity of Dioscorides in seeking out the uses of plants, and the industry of the writers on husbandry, especially among the Romans, in the advancement of agriculture. After the revival of literature, the first employment of botanists was to rescue from total destruction and oblivion the ruins of ancient erudition; but after some time, not finding their acquisitions pay for the labour spent in the search, they began to turn their attention to nature herself, and to describe plants from their observations, till they became so overwhelmed with the multitude of species, as almost to despair of finding the way in or out of their gardens; both the Indies daily furnishing them with so many novelties, that no memory was strong enough to retain them. At length systematic writers undertook to describe every plant according to its fructification, by this means to distinguish them from each other, and arrange them in a methodical manner; which undertaking has employed them to the present day. But as these very authors bestowed their chief attention upon the corolla and the fruit, the former because its beauty attracts the eye, and the latter because most remarkable for its use, it so happened that they did not take time to duly consider the minuter parts of the flower, till they found the larger quite insufficient to discriminate the immense numbers of vegetables, which were daily augmenting the catalogue of Flora. The later botanists have therefore been obliged to examine attentively everything that they were able to discover in the fructification, in order to find there certain and convenient marks of distinction. Among these parts, the stamina and pistilla, although generally very minute bodies, and on that account contemptuously neglected by former observers, were found so essential, that no flower could be discovered destitute of them. Hence these organs have ever since been reckoned of great moment, have obtained particular names, and their different parts have also been enumerated.

To say precisely who first discovered the sexes of plants, would be a work of the greatest difficulty, and of no kind of use. Many discoveries have proceeded gradually towards perfection, as rivers, although small and insignificant at their origin, by the addition of fresh streams in their course, become able at length to bear ships of the greatest burden. It cannot be denied, that the ancient cultivators of Palms, Figs, and Pistacia, were acquainted with this fact, at least in those trees, for they knew the necessity of suspending the male flowers over the female, in order to obtain fruit. Nor is it less certain, that the oldest writers have expressly mentioned the sexes of plants. But how little real knowledge of the matter they possessed, and on what slight grounds they held it, appears from their having frequently described plants as being severally male and female, which were not so. Nay, after the revival of literature, even in the last century, botanists retained so much of the ignorance of former times, that the most eminent teachers of the science, attempting to discriminate the sexes, very often called the female plant the male; which affords the most decisive proof of their ignorance that could possibly have been given.

Sir Thomas Millington, an Englishman, is handed down to us, by his countrymen, as the first discoverer of this doctrine, if he be entitled to the honor of a discovery, who left no information in writing of what he had observed. It is pretended that he was perfectly acquainted with the fact about the year 1676; and indeed, a very little while after him, Grew and Ray, both Englishmen, appear to have gone a good way in the discovery. Rud. Jac. Camerarius, and other authors, have explained a great number of particulars, but no one has done more than Vaillant, the great French botanist, who in an academical oration, published by Boerhaave, discovers an accurate knowledge of the fact, although he has not demonstrated it by arguments.

From that time, that is, from the year 1718, many have laboured to promote this opinion, especially the author of the Sexual System, who believes he has, in a number of different publications, clearly and decisively established the truth of it; although Pontedera has endeavored to refute him, and Alston has even, very lately, treated him with derision.

That the subject may be properly understood, it is in the first place necessary that we should accurately understand the nature of vegetable bodies.

The organs common in general to all plants are: 1st, The root, with its capillary vessels, extracting nourishment from the ground. 2nd. The leaves, which may be called the limbs, and which, like the feet and wings of animals, are organs of motion; for being themselves shaken by the external air, they shake and exercise the plant. 3rd. The trunk, containing the medullary substance, which is nourished by the bark, and for the most part multiplied into several compound plants. 4th. The fructification, which is the true body of the plant, set at liberty by a metamorphosis, and consists only of the organs of generation; it is often defended by a calyx, and furnished with petals, by means of which it in a manner flutters in the air.

Many flowers have no calyx, as several of the lily tribe, the Hippuris, etc., many want the corolla, as grasses, and the plants called apetalous; but there are none more destitute of stamina and pistilla, those important organs destined to the formation of fruit. We therefore infer from experience that the stamina are the male organs of generation, and the pistilla of the female; and as many flowers are furnished with both at once, it follows that such flowers are hermaphrodites. Nor is this so wonderful, as that there should be any plants in which the different sexes are distinct individuals; for plants being immovably fixed to one spot, cannot like animals, travel in search of a mate. There exists, however, in some plants a real difference of sex. From seeds of the same mother, some individuals shall be produced, whose flowers exhibit stamina without pistilla, and may therefore properly be called male; while the rest being furnished with pistilla without stamina are therefore denominated females; and so uniformly does this take place, that no vegetable was ever found to produce female flowers without flowers furnished with stamina being produced, either on the same individual or on another plant of the same species, and *vice versa.*

As all seed vessels are destined to produce seeds, so are the stamina to bear the pollen, or fecundating powder. All seeds contain within their membranes a certain medullary substance, which swells when dipped into warm water. All pollen, likewise, contains in its membrane an elastic substance, which, although very subtle, and almost invisible, by means of warm water often explodes with great vehemence. While plants are in flower, the pollen falls from their antheræ, and is dispersed abroad, as seeds are dislodged from their situation when the fruit is ripe. At the same time that the pollen is scattered, the pistillum presents its stigma, which is then in its highest vigour, and, for a portion of the day at least, it moistened with a fine dew. The stamina either surround this stigma, or if the flowers are of the drooping kind, they are bent towards one side, so that the pollen can easily find access to the stigma, where it not only adheres by means of the dew of that part, but the moisture occasions its bursting, by which means its contents are discharged. That issued from it being mixed with the fluid of the stigma, is conveyed to the rudiments of the seed. Many evident instances of this present themselves to our notice; but I have nowhere seen it more manifest than in the Jacobean Lily (*Amarylis formosissima*), the pistillum of which, when sufficient heat is given the plant to make it flower in perfection, is bent downwards and from its stigma issues a drop of limpid fluid, so large that one would think it in danger of falling to the ground. It is, however, gradually reabsorbed into the style about three or four o'clock and becomes invisible until about ten the next morning, when it appears again; by noon it attains its largest dimensions; and in the afternoon, by a gentle and scarcely perceptible decrease it returns to its source. If we shake the antheræ over the stigma, so that the pollen may fall on this limpid drop, we see the fluid soon after become turbid and assume a yellow color; and we perceive little rivulets, or opaque streaks running from the stigma towards the rudiments of the seed. Some time afterwards, when the drop has totally disappeared, the pollen may be observed adhering to the stigma, but of an irregular figure, having lost its original form. No one, therefore, can assent to what Morland and others have asserted, that the pollen passes into the stigma, pervades the style and enters the tender rudiments of the seed, as Leeuwenhoeck supposed his worms to enter the ova. A most evident proof of the falsehood of this opinion may be obtained from any species of Mirabilis (Marvel of Peru), whose pollen is so very large that it almost exceeds the style itself in thickness, and, falling on the stigma, adheres firmly to it; that organ sucking and exhausting the pollen, as a cuttle fish devours everything that comes within its grasp. One evening in the month of August, I removed all the stamina from three flowers of the Mirabilis longiflora, at the same time destroying all the rest of the flowers which were expanded; I sprinkled these three flowers with the pollen of Mirabilis Jalappa; the seed-buds swelled, but did not ripen. Another evening I performed a similar experiment, only sprinkling the flowers with the pollen of the same species; all these flowers produced ripe seeds.

Some writers have believed that the stamina are parts of the fructification, which serve only to discharge an impure or excrementitious matter, and by no means formed for so important a work as generation. But it is very evident that these authors have not sufficiently examined the subject; for, as in many vegetables, some flowers are furnished with stamina only, and others only with pistilla; it is altogether impossible that stamina situated at so very great a distance from the fruit, as on a different branch, or perhaps on a separate plant, should serve to convey any impurities from the embryo.

No physiologist could demonstrate, *a priori*, the necessity of the masculine fluid to the rendering the eggs of animals prolific, but experience has established it beyond a doubt. We therefore judge *a posteriori* principally, of the same effect in plants.

In the month of January, 1760, the *Antholyza Cunonia* flowered in a pot in my parlour, but produced no fruit, the air of the room not being sufficiently agitated to waft the pollen to the stigma. One day, about noon, feeling the stigma very moist, I plucked off one of the antheræ, by means of a fine pair of forceps, and gently rubbed it on one part of the expanded stigmata. The spike of flowers remained eight or ten days longer; when I observed, in gathering the branch for my herbarium, that the fruit of that flower only on which the experiment had been made, had swelled to the size of a bean. I then dissected this fruit and discovered that one of the three cells contained seeds in considerable number, the other two being entirely withered.

In the month of April I sowed the seeds of hemp (*Cannabis*) in two different pots. The young plants came up so plentifully, that each pot contained thirty or forty. I placed each by the light of a window, but in different and remote apartments. The hemp grew extremely well in both pots. In one of them I permitted the male and female plants to remain together, to flower and bear fruit, which ripened in July, being macerated in water, and committed to the earth, sprung up in twelve days. From the other, however, I removed all the male plants, as soon as they were old enough for me to distinguish them from the females. The remaining females grew very well, and presented their long pistilla in great abundance, these flowers continuing a very long time, as if in expectation of their mates; while the plants in the other pot had already ripened their fruit, their pistilla having, quite in a different manner, faded as soon as the males had discharged all their pollen. It was truly a beautiful and truly admirable spectacle to see the unimpregnated females preserve their pistilla so long green and flourishing, not permitting them to begin to fade till they had been for a very considerable time exposed in vain, to the access of the male pollen.

Afterwards, when these virgin plants began to decay through age, I examined all their calyces in the presence of several botanists and found them large and flourishing, although every one of the seed-buds was brown, compressed, membranaceous, and dry, not exhibiting any appearance of cotyledons or pulp. Hence I am perfectly convinced that the circumstance which authors have recorded, of the female hemp having produced seeds, although deprived of the male, could only have happened by means of pollen brought by the wind from some distant place. No experiment can be more easily performed than the above; none more satisfactory in demonstrating the generation of plants.

The *Clutia tenella* was in like manner kept growing in my window during the months of June and July. The male plant was in one pot, the female in another. The latter abounded with fruit, not one of its flowers proving abortive. I removed the two pots into different windows of the same apartment; still all the female flowers continued to become fruitful. At length I took away the male entirely, leaving the female alone, and cutting off all the flowers which it had already borne. Every day new ones appeared from the axila of every leaf; each remained eight or ten days, after which their foot stalks turning yellow, they fell barren to the ground. A botanical friend, who had amused himself with observing this phenomenon with me, persuaded me to bring, from the stove in the garden, a single male flower, which he placed over one of the female ones, then in perfection, tying a piece of red silk around its pistillum. The next day the male flower was taken away, and this single seed-bud remained, and bore fruit. Afterwards I took another male flower out of the same stove, and with a pair of slender forceps pinched off one of its antheræ, which I afterwards gently scratched with a feather, so that a very small portion of its pollen was discharged upon one of the three stigmata of a female flower, the other two stigmata being covered with paper. This fruit likewise attained its due size, and on being cut transversely, exhibited one cell filled with a large seed, and the other two empty. The rest of the flowers, being unimpregnated, faded and fell off. This experiment may be performed with as little trouble as the former.

The *Datifca cannabina* came up in my garden from seed ten years ago, and has every year been plentifully increased by means of its perennial root. Flowers in great number have been produced by it; but, being all female, they proved abortive. Being desirous of producing male plants, I obtained more seeds from Paris. Some more plants were raised; but these likewise to my great mortification, all proved females, and bore flowers, but no fruit. In the year 1757 I received another parcel of seeds. From these I obtained a few male plants, which flowered in 1758. These were planted at a great distance from the females; and when their flowers were just ready to emit their pollen, holding a paper under them, I gently shook the spike of panicle with my finger, till the paper was almost covered with the yellow powder. I carried this to the females, which were flowering in another part of the garden, and placed it over them. The cold nights of the year in which this experiment was made, destroyed these Datifcas, with many other plants, much earlier than usual. Nevertheless, when I examined the flowers of those plants, which I had sprinkled with the fertilizing powder, I found the seeds of their due magnitude; while in the more remote Datifcas, which had not been impregnated with pollen, no traces of seeds were visible.

Several species of Momordica, cultivated by us, like other Indian vegetables, in close stoves, have frequently borne female flowers; which, although at first very vigorous, after a short time have constantly faded and turned yellow, without perfecting any seed, till I instructed the gardener, as soon as he observed a female flower, to gather a male one, and place it above the female. By this contrivance we are so certain of obtaining fruit that we dare pledge ourselves to make any female flowers fertile that shall be fixed on.

The *Jatropha urens* has flowered every year in my hot-house; but the female flowers coming before the males, in a week's time dropped their petals and faded before the latter were opened; from which cause no fruit has been produced, but the *germina* themselves have fallen off. We have therefore never had any fruit of the Jatropha till the year 1752, when the male flowers were in vigour on a tall tree, at the same time that the females began to appear on a small Jatropha which was growing in a garden-pot. I placed this pot under the other tree, by which means the female flowers bore seeds, which grew in being sown. I have frequently amused myself with taking the male flowers from one plant, and scattering them over the female flowers of another, and have always found the seeds of the latter impregnated by it.

Two years ago I placed a piece of paper under some of these male flowers and afterwards folded up the pollen which had fallen upon it, preserving it so folded up, if I remember right, four or six weeks, at the end of which time another branch of the same Jatropha was in flower. I then took the pollen, which I had so long preserved in paper, and strewed it over three female flowers, the only ones at that time expanded. These three females proved fruitful, while all the rest, which grew in the same bunch, fell off abortive.

The interior petals of the Ornithogalum, commonly, but improperly called Canadense, cohere so closely together that they only just admit the air to the germen and will scarcely permit the pollen of another flower to pass; this plant produced every day new flowers and fruit, the fructification never failing in any instance; I therefore, with the utmost care, extracted the antheræ from one of the flowers with a hooked needle, and as I hoped, this single flower proved barren. This experiment was repeated about a week after with the same success.

I removed all of the antheræ out of a flower of *Chelidonium corniculatum* (scarlet-horned poppy), which was growing in a remote part of the garden, upon the first opening of its petals, and stripped off all the rest of the flowers; another day I treated another flower of the same plant in a similar manner, but sprinkled the pistillum of this with the pollen borrowed from another plant of the same species; the result was, that the first flower produced no fruit, but the second afforded very perfect seed. My design in this experiment was to prove that the mere removal of the antheræ from a flower is not in itself sufficient to render the germen abortive.

Having the *Nicotiana fruticosa* growing in a garden-pot, and producing plenty of flowers and seed, I extracted the antheræ from the newly expanded flowers before they had burst, at the same time cutting away all the other flowers; this germen produced no fruit, nor did it even swell.

I removed an urn, in which the *Asphodelus fistulosus* was growing, to one corner of the garden, and from one of the flowers which had lately opened, I extracted its antheræ; this caused the impregnation to fail. Another day I treated another flower in the same manner; but, bringing a flower from a plant in a different part of the garden, with which I sprinkled the pistillum of the mutilated one, its germen became by that means fruitful.

Ixia chinensis, flowering in my stove, the windows of which were shut, all its flowers proved abortive. I therefore took one of its antheræ in a pair of pincers, and with them sprinkled the stigmata of two flowers, and the next day one stigma only of a third flower; the seed-buds of these flowers remained, grew to a large size and bore seed, the fruit of the third, however, contained ripe seed only in one of its cells.

To relate more experiments would only be to fatigue the reader unnecessarily. All nature proclaims the truth I have endeavored to inculcate, and every flower bears witness to it. Any person may make the experiment for himself with any plant he pleases, only taking care to place the pot in which it is growing, in the window of a room sufficiently out of reach of other flowers; and I will venture to promise him that he will obtain no perfect fruit unless pollen has access to the pistillum.

Logan's experiments on the Mays are perfectly satisfactory, and manifestly show that the pollen does not enter the style, or arrive at the germen, but that it is exhausted by the genital fluid of the pistillum. And as in animals no conception can take place, unless the genital fluid of the female be discharged at the same moment as the impregnating liquor of the male; so in plants, generation fails, unless the stigma be moist with prolific dew.

Husbandmen know, by long experience, that if rain falls while rye is in flower, by coagulating the pollen of its antheræ, it occasions the emptiness of many husks in the ear.

Gardeners remark the same thing every year in fruit trees. Their blossoms produce no fruit if they have unfortunately been exposed to long-continued rains.

Aquatic plants rise above the water at the time of flowering, and afterwards again subside, for no other reason, than that the pollen may safely reach the stigma.

The white water-lily (*Nymphaea alba*) raises itself every morning out of the water and opens its flowers, so that by noon at least three inches of its flower-stalk may be seen above the surface. In the evening it is closely shut up, and withdrawn again; for about four o'clock in the afternoon the flower closes, and remains all night under water; which was observed full two thousand years since, even as long ago as the time of Theophrastus, who has described this circumstance in the *Nymphaea Lotus,* a plant so much resembling our white water-lily that they are only distinguished from each other by the leaves of the Lotus being indented. Theophrastus gives the following account of this vegetable, in his History of Plants, book IV., chap. 10: "It is said to withdraw its flowers into the Euphrates, which continue to descend till midnight, to so great a depth that at daybreak they are out of reach of the hand; after which it rises again, and in the course of the morning appears above the water, and expands its flowers, rising higher and higher, till it is a considerable height above the surface." The very same thing may be observed in the *Nymphaea alba.*

Many flowers close themselves in the evening and before rain, lest the pollen should be coagulated; but after the discharge of the pollen they always remain open. Such of them as do not shut up, incline their flowers downward in those circumstances, and several flowers, which come forth in the moisture of spring, droop perpetually. The manner in which the Parnassia and Saxigrage move their antheræ to the stigma is well known. The common Rue, a plant everywhere to be met with, moves one of its antheræ every day to the stigma, till all of them in their turns have deposited their pollen there.

The Neapolitan star flower (*ornithogalum nutans*) has six broad stamina, which stand close together in the form of a bell, the three external ones being but half the length of the others; so that it seems impossible for their antheræ ever to convey their pollen to the stigma; but nature, by an admirable contrivance, bends the summits of these external stamina inwards between the other filaments, so that they are enabled to accomplish their purpose.

The Plaintain tree (*Musa*) bears two kinds of hermaphrodite flowers; some have imperfect antheræ, others only the rudiments of stigmata; as the last mentioned kind appear after the others, they cannot impregnate them, consequently no seeds are produced in our gardens, and scarcely ever on the plants cultivated in India. An event happened this year, which I have long wished for; two plaintain-trees flowering with me so fortunately that one of them brought forth its first female blossoms at the time that male ones began to appear on the other. I eagerly ran to collect antheræ from the first plant, in order to scatter them over the newly-expanded females, in hopes of obtaining seed from them, which no botanist has yet been able to do. But when I came to examine the antheræ I found even the largest of them absolutely empty and void of pollen, consequently unfit for impregnating the females; the seeds of this plant, therefore, can never be perfected in our gardens. I do not doubt, however, that real male plants of this species may be found in its native country, bearing flowers without fruit, which the gardeners have neglected; while the females in this country produce imperfect fruit, without seeds, like the female fig; and, like that tree, are increased easily by suckers. The fruit, therefore, of the plaintain-tree scarcely attains anything like its due size, the larger seed-buds only ripening, without containing anything in them.

The day would sooner fail me than examples. A female date-bearing palm flowered many years at Berlin, without producing any seeds. But the Berlin people taking care to have some of the blossoms of the male tree, which was then flowering at Leipsic, sent them by the post, they obtained fruit by that means; and some dates, the offspring of this impregnation, being planted in my garden, sprung up, and to this day continue to grow vigorously. Kœmpfer formerly told us how necessary it was found by the oriental people, who live upon the produce of palm-trees, and are the true Lotophagi, to plant some male trees among the females, if they hoped for any fruit; hence, it is the practice of those who make war in that part of the world to cut down all the male palms, that a famine may afflict their proprietors; sometimes even the inhabitants themselves destroy the male trees, when they dread an invasion, that their enemies may find no sustenance in the country.

Leaving these instances, and innumerable others, which are so well known to botanists that they would by no means bear the appearance of novelty, and can only be doubted by those persons who neither have observed nature, nor will they take the trouble to study her, I pass to a fresh subject, concerning which much new light is wanted; I mean hybrid, or mule vegetables, the existence and origin of which we shall now consider.

I shall enumerate three or four real mule plants, to whose origin I have been an eye-witness.

1. *Veronica spuria,* described in Amœnitates Acad. vol. III. p. 35, came from the impregnation of *Veronic maratima* by *Verbena officinalis;* it is easily propagated by cuttings, and agrees perfectly with its mother in fructification, and with its father in leaves.

2. *Delphinium hybridum,* sprung up in a part of the garden where *Delphinium clatum* and *Aconitum Napellus* grew together; it resembles its mother as much in its internal parts, that is, in fructification as it does its father (the *Aconitum*) in outward structure, or leaves; and, owing its origin to plants so nearly allied to each other, it propagates itself by seed; some of which I now send with this Dissertation.

3. *Hieracium Taraxici,* gathered in 1753 upon our mountains by Dr. Solander, in its thick, brown, woolly calyx; in its stem being hairy towards the top, and in its bracteæ, as well as in every parts of its fructification, resembles so perfectly its mother, *Hieracium alpinum,* that an inexperienced person might mistake one for the other; but in the smoothness of its leaves, in their indentations and whole structure, it so manifestly agrees with its father, *Leontodon Taraxacum* (Dandelion), that there can be no doubt of its origin.

4. *Tragopogon hybridum* attracted my notice the autumn before last, in a part of the garden where I had planted *Tragopogon pratense,* and *Tragopogon porrifolium*; but winter coming on, destroyed its seeds. Last year, while the *Tragopogon pratense* was in flower I rubbed off its pollen early in the morning, and about eight o'clock sprinkled its stigmata with some pollen of the *Tragopogon porrifolium,* marking the calyces by tying a thread round them. I afterwards gathered the seeds when ripe, and sowed them that autumn in another place; they grew, and produced this year, 1759, purple flowers yellow at the base, seeds of which I now send. I doubt whether any experiment demonstrates the generation of plants more certainly than this.

There can be no doubt that these are all new species produced by hybrid generation. And hence we learn, that a mule offspring is the exact image of its mother in its medullary substance, internal nature, or fructification, but resembles its father in leaves. This is a foundation upon which naturalists may build much. For it seems probable that many plants, which now appear different species of the same *genus,* may in the beginning have been but one plant, having arisen merely from hybrid generation. Many of those Geraniums which grow at the Cape of Good Hope, and have never been found wild anywhere but in the south parts of Africa, and which, as they are distinguished from all other Geraniums by their single-leaved calyx, many-flowered foot-stalk, irregular corolla, seven fertile stamina, and three mutilated ones, and by their naked seeds furnished with downy awns; so they agree together in all these characters, although very various in their roots, stems and leaves; these Geraniums, I say, would almost induce a botanist to believe that the species of one *genus* in vegetables are only so many different plants as there have been different associations with the flowers of one species, and consequently a *genus* is nothing else than a number of plants sprung from the same mother by different fathers. But whether all these species be the offspring of time; whether, in the beginning of all things, the Creator limited the number of future species, I dare not presume to determine. I am, however, convinced this mode of multiplying plants does not interfere with the system or general scheme of nature; as I daily observe that insects, which live upon one species of a particular *genus,* are contented with another of the same *genus.*

A person who has once seen the *Achyranthes aspera,* and remarked its spike, the parts of its flower, its small and peculiarly formed nectaria, as well as its calyces bent backwards as the fruit ripens, would think it very easy at any time to distinguish these flowers from all others in the universe; but when he finds the flowers of *Achyranthes indica* agreeing with them even in their minutest parts, and at the same time observes the large, thick, obtuse, undulated leaves of the last-mentioned plant, he will think he sees *Achyranthes aspera* masked in the foliage of *Xanthium strumarium.* But I forbear to mention any more instances.

Here is a new employment for botanists, to attempt the production of new species of vegetables by scattering the pollen of various plants over various widowed females. And if these remarks should meet with a favourable reception, I shall be the more induced to dedicate what remains of my life to such experiments, which recommend themselves by being at the same time agreeable and useful. I am persuaded by many considerations that those numerous and most valuable varieties of plants which are used for culinary purposes, have been produced in this manner, as the several kinds of cabbages, lettuces, etc.; and I apprehend this is the reason of their not being changed by a difference of soil. Hence I cannot give my assent to the opinion of those who imagine all varieties to have been occasioned by change of soil; for, if this were the case, the plants would return to their original form, if removed again to their original situation.

FRANKLIN

Benjamin Franklin was born in Boston, January 6, 1706. How he ran away from his brother to whom he was apprenticed, how he struggled at his printer's trade in Philadelphia, London and again in Philadelphia, until he finally reached success, ought to be familiar to all from his autobiography. His paper, the Gazette, became probably the best of the colonial sheets, and his Poor Richard's Almanac, first published in 1732, made him famous on two continents. A police force, city care of the streets, fire companies, a public library, a city academy, all of these movements in Philadelphia owed their origin to him. Later he brought about the establishment of postoffices and post roads. In 1746 he began making his experiments in electricity which reached their climax in his identification of electricity with lightning. The immense significance of this experiment was to show the infinite power of electricity.

From 1757 to 1762 he was in London as spokesman of the assembly on the question of the Penn estates in the colony being taxed.

In 1764 he returned to London as representative of the colonists against the stamp duty and taxation without representation. When in 1775 he again arrived in Philadelphia he was at once sent as a delegate to the Continental congress, and after the Declaration of Independence was signed, was dispatched to France as a commissioner of the colonies. To him more than any one man was due the aid given by France.

He was in France until 1783. In 1787 he was made a member of the convention to frame a new constitution, and did much to further its construction.

He died in 1790, great as a journalist and writer, as a scientist, a statesman, a diplomat, and a man of affairs.

TO PETER COLLINSON

Wonderful Effect of Points—Positive and Negative Electricity—Electrical Kiss—Counterfeit Spider—Simple and Commodious Electrical Machine.

Philadelphia, 11 July, 1747.

SIR,

In my last I informed you that, in pursuing our electrical inquiries, we had observed some particular phenomena, which we looked upon to be new, and of which I promised to give you some account, although I apprehended they might not possibly be new to you, as so many hands are daily employed in electrical experiments on your side of the water, some or other of which would probably hit on the same observations.

The first is the wonderful effect of pointed bodies, both in drawing off and throwing off electrical fire. For example:

Place an iron shot, of three or four inches diameter, on the mouth of a clean, dry glass bottle. By a fine silken thread from the ceiling, right over the mouth of the bottle, suspend a small cork ball, about the bigness of a marble; the thread of such a length as that the cork ball may rest against the side of the shot. Electrify the shot, and the ball will be repelled to the distance of four or five inches, more or less, according to the quantity of electricity. When in this state, if you present to the shot, the point of a long, slender, sharp bodkin, at six or eight inches distance, the repellency is instantly destroyed, and the cork flies to the shot. A blunt body must be brought within an inch, and draw a spark, to produce the same effect. To prove that the electrical fire is drawn off by the point, if you take the blade of the bodkin out of the wooden handle, and fix it in a stick of sealing-wax, and then present it at the distance aforesaid, or if you bring it very near, no such effect follows; but sliding one finger along the wax till you touch the blade, and the ball flies to the shot immediately. If you present the point in the dark, you will see, sometimes at a foot distance and more, a light gather upon it, like that of a fire-fly, or glow-worm; the less sharp the point, the nearer you must bring it to observe the light; and, at whatever distance you see the light, you may draw off the electrical fire and destroy the repellency. If a cork ball so suspended be repelled by the tube, and a point be presented quick to it, though at a considerable distance, it is surprising to see how suddenly it flies back to the tube. Points of wood will do near as well as those of iron, provided the wood is not dry; for perfectly dry wood will no more conduct electricity than sealing-wax.

To show that points will throw off as well as draw off the electrical fire; lay a long, sharp needle upon the shot, and you cannot electrize the shot so as to make it repel the cork ball. Or fix a needle to the end of a suspended gun-barrel, or iron rod, so as to point beyond it, like a little bayonet; and, while it remains there, the gun-barrel, or rod, cannot by applying the tube to the other end be electrized so as to give a spark, the fire continually running out silently at the point. In the dark you may see it make the same appearance as it does in the case before mentioned.

The repellency between the cork ball and the shot is likewise destroyed; 1st, by sifting fine sand on it; this does it gradually; 2dly, by breathing on it; 3dly, by making a smoke about it from burning wood; 4thly, by candle-light, even though the candle is at a foot distance; these do it suddenly. The light of a bright coal from a wood fire, and the light of a red-hot iron, do it likewise; but not at so great a distance. Smoke, from dry rosin dropped on hot iron, does not destroy the repellency; but is attracted by both shot and cork ball, forming proportionate atmospheres round them, making them look beautifully, somewhat like some of the figures in Burnet's or Whiston's Theory of the Earth.

N. B. This experiment should be made in a closet, where the air is very still, or it will be apt to fail.

The light of the sun thrown strongly on both cork and shot by a looking-glass, for a long time together, does not impair the repellency in the least. This difference between fire-light and sun-light is another thing that seems new and extraordinary to us.

We had for some time been of the opinion, that the electrical fire was not created by friction, but collected, being really an element diffused among, and attracted by, other matter, particularly by water and metals. We had even discovered and demonstrated its afflux to the electrical sphere, as well as its efflux, by means of little, light windmill wheels, made of stiff paper vanes, fixed obliquely, and turning freely on fine wire axes; also by little wheels, of the same matter, but formed like water-wheels. Of the disposition and application of which wheels, and the various phenomena resulting, I could, if I had time, fill you a sheet. The impossibility of electrizing one's self (though standing on wax) by rubbing the tube, and drawing the fire from it; and the manner of doing it, by passing the tube near a person or thing standing on the floor, &c., had also occurred to us some months before Mr. Watson's ingenious Sequel came to hand; and these were some of the new things I intended to have communicated to you. But now I need only mention some particulars not hinted in that piece, with our reasonings thereupon; though perhaps the latter might well enough be spared.

1. A person standing on wax, and rubbing the tube, and another person on wax drawing the fire, they will both of them (provided they do not stand so as to touch one another) appear to be electrized, to a person standing on the floor; that is, he will perceive a spark on approaching each of them with his knuckle.

2. But if the persons on wax touch one another during the exciting of the tube, neither of them will appear to be electrized.

3. If they touch one another after exciting the tube and drawing the fire as aforesaid, there will be a stronger spark between them, than was between either of them and the person on the floor.

4. After such strong spark neither of them discover any electricity.

These appearances we attempt to account for thus. We suppose, as aforesaid, that electrical fire is a common element, of which every one of the three persons above mentioned has his equal share, before any operation is begun with the tube. A, who stands on wax and rubs the tube, collects the electrical fire from himself into the glass; and, his communication with the common stock being cut off by the wax, his body is not again immediately supplied. B, (who stands on wax likewise) passing his knuckle along near the tube, receives the fire which was collected by the glass from A; and his communication with the common stock being likewise cut off, he retains the additional quantity received. To C, standing on the floor, both appear to be electrized; for he, having only the middle quantity of electrical fire, receives a spark upon approaching B, who has an over-quantity; but gives one to A, who has an under-quantity. If A and B approach to touch each other, the spark is stronger, because the difference between them is greater. After such touch there is no spark between either of them and C, because the electrical fire in all is reduced to the original equality. If they touch while electrizing, the equality is never destroyed, the fire only circulating. Hence have arisen some new terms among us; we say B (and bodies like circumstanced) is electrized positively; A, negatively. Or rather B is electrized plus; A, minus. And we daily in our experiments electrize bodies plus or minus, as we think proper. To electrize plus or minus, no more needs to be known than this, that the parts of the tube or sphere that are rubbed, do, in the instant of the friction, attract the electrical fire, and therefore take it from the thing rubbing; the same parts immediately, as the friction upon them ceases, are disposed to give the fire they have received to any body that has less. Thus you may circulate it, as Mr. Watson has shown; you may also accumulate or subtract it, upon or from any body, as you connect that body with the rubber, or with the receiver, the communication with the common stock being cut off. We think that ingenious gentleman was deceived when he imagined (in his Sequel), that electrical fire came down the wire from the ceiling to the gun-barrel, thence to the sphere, and so electrized the machine and the man turning the wheel, &c. We suppose it was driven off, and not brought on through that wire; and that the machine and man, &c., were electrized minus, that is, had less electrical fire in them than things in common.

As the vessel is just upon sailing, I cannot give you so large an account of American electricity as I intended; I shall only mention a few particulars more. We find granulated lead better to fill the phial with, than water, being easily warmed, and keeping warm and dry in damp air. We fire spirits with the wire of the phial. We light candles, just blown out, by drawing a spark among the smoke, between the wire and snuffers. We represent lightning, by passing the wire in the dark, over a China plate, that has gilt flowers, or applying it to gilt frames of looking-glasses, &c. We electrize a person twenty or more times running, with a touch of the finger on the wire, thus; He stands on wax. Give him the electrized bottle in his hand. Touch the wire with your finger, and then touch his hand or face; there are sparks every time. We increase the force of the electrical kiss vastly, thus; Let A and B stand on wax; or A on wax and B on the floor; give one of them the electrized phial in his hand; let the other take hold of the wire; there will be a small spark; but when their lips approach, they will be struck and shocked. The same, if another gentleman and lady, C and D, standing also on wax, and joining hands with A and B, salute or shake hands. We suspend by fine silk thread a counterfeit spider, made of a small piece of burnt cork, with legs of linen thread, and a grain or two of lead stuck in him, to give him more weight. Upon the table, over which he hangs, we stick a wire upright, as high as the phial and wire, four or five inches from the spider; then we animate him, by setting the electrified phial at the same distance on the other side of him; he will immediately fly to the wire of the phial, bend his legs in touching it, then spring off, and fly to the wire in the table; thence again to the wire of the phial, playing with his legs against both, in a very entertaining manner, appearing perfectly alive to persons unacquainted. He will continue this motion an hour or more in dry weather. We electrify, upon wax in the dark, a book that has a double line of gold round upon the covers, and then apply a knuckle to the gilding; the fire appears everywhere upon the gold like a flash of lightning; not upon the leather, nor if you touch the leather instead of the gold. We rub our tubes with buckskin, and observe always to keep the same side to the tube, and never to sully the tube by handling; thus they work readily and easily, without the least fatigue, especially if kept in tight pasteboard cases, lined with flannel, and sitting close to the tube. This I mention, because the European papers on electricity frequently speak of rubbing the tube as a fatiguing exercise. Our spheres are fixed upon iron axes, which pass through them. At one end of the axis there is a small handle, with which you turn the sphere like a common grindstone. This we find very commodious, as the machine takes up but little room, is portable, and may be enclosed in a tight box, when not in use. It is true, the sphere does not turn so swift as when the great wheel is used; but swiftness we think of little importance, since a few turns will charge the phial, &c., sufficiently.

I am, &c.

B. Franklin.

THE IDENTITY OF LIGHTNING AND ELECTRICITY. THE LIGHTNING ROD

But points have a property, by which they draw on as well as throw off the electrical fluid, at greater distances than blunt bodies can. That is, as the pointed part of an electrified body will discharge the atmosphere of that body, or communicate it farthest to another body, so the point of an unelectrified body will draw off the electrical atmosphere from an electrified body, farther than a blunter part of the same unelectrified body will do. Thus, a pin held by the head, and the point presented to an electrified body, will draw off its atmosphere at a foot distance; where, if the head were presented instead of the point, no such effect would follow. To understand this, we may consider, that, if a person standing on the floor would draw off the electrical atmosphere from an electrified body, an iron crow and a blunt knitting-needle, held alternately in his hand, and presented for that purpose, do not draw with different forces in proportion to their different masses. For the man, and what he holds in his hand, be it large or small, are connected with the common mass of unelectrified matter; and the force with which he draws is the same in both cases, it consisting in the different proportion of electricity in the electrified body, and that common mass. But the force, with which the electrified body retains its atmosphere by attracting it, is proportioned to the surface over which the particles are placed; that is, four square inches of that surface retain their atmosphere with four times the force that one square inch retains its atmosphere. And, as in plucking the hairs from the horse's tail, a degree of strength not sufficient to pull away a handful at once, could yet easily strip it hair by hair, so a blunt body presented cannot draw off a number of particles at once, but a pointed one, with no greater force, takes them away easily, particle by particle.

These explanations of the power and operation of points, when they first occurred to me, and while they first floated in my mind, appeared perfectly satisfactory; but now I have written them, and considered them more closely, I must own I have some doubts about them; yet, as I have at present nothing better to offer in their stead, I do not cross them out; for, even a bad solution read, and its faults discovered, has often given rise to a good one, in the mind of an ingenious reader.

Nor is it of much importance to us to know the manner in which nature executes her laws; it is enough if we know the laws themselves. It is of real use to know that China left in the air unsupported, will fall and break; but how it comes to fall, and why it breaks, are matters of speculation. It is a pleasure indeed to know them, but we can preserve our China without it.

Thus, in the present case, to know this power of points may possibly be of some use to mankind, though we should never be able to explain it. The following experiments, as well as those in my first paper, show this power. I have a large prime conductor, made of several thin sheets of clothier's pasteboard, formed into a tube, near ten feet long and a foot diameter. It is covered with Dutch embossed paper, almost totally gilt. This large metallic surface supports a much greater electrical atmosphere than a rod of iron of fifty times the weight would do. It is suspended by silk lines, and when charged will strike, at near two inches distance, a pretty hard stroke, so as to make one's knuckle ache. Let a person standing on the floor present the point of a needle, at twelve or more inches distance from it, and while the needle is so presented, the conductor cannot be charged, the point drawing off the fire as fast as it is thrown on by the electrical globe. Let it be charged, and then present the point at the same distance, and it will suddenly be discharged. In the dark you may see the light on the point, when the experiment is made. And if the person holding the point stands upon wax, he will be electrified by receiving the fire at that distance. Attempt to draw off the electricity with a blunt body, as a bolt of iron round at the end, and smooth, (a silversmith's iron punch, inch thick, is what I use,) and you must bring it within the distance of three inches before you can do it, and then it is done with a stroke and crack. As the pasteboard tube hangs loose on silk lines, when you approach it with the punch-iron, it likewise will move towards the punch, being attracted while it is charged; but if, at the same instant, a point be presented as before, it retires again, for the point discharges it. Take a pair of large brass scales, of two or more feet beam, the cords of the scales being silk. Suspend the beam by a pack-thread from the ceiling, so that the bottom of the scales may be about a foot from the floor; the scales will move round in a circle by the untwisting of the pack-thread. Set the iron punch on the end upon the floor, in such a place as that the scales may pass over it in making their circle; then electrify one scale by applying the wire of a charged phial to it. As they move round, you see that scale draw nigher to the floor, and dip more when it comes over the punch; and, if that be placed at a proper distance, the scale will snap and discharge its fire into it. But, if a needle be stuck on the end of the punch, its point upward, the scale, instead of drawing nigh to the punch, and snapping, discharges its fire silently through the point, and rises higher from the punch. Nay, even if the needle be placed upon the floor near the punch, its point upwards, the end of the punch, though so much higher than the needle, will not attract the scale and receive its fire, for the needle will get it and convey it away, before it comes nigh enough for the punch to act. And this is constantly observable in these experiments, that the greater quantity of electricity on the pasteboard tube, the farther it strikes or discharges its fire, and the point likewise will draw it off at a still greater distance.

Now if the fire of electricity and that of lightning be the same, as I have endeavoured to show at large in a former paper, this pasteboard tube and these scales may represent electrified clouds. If a tube of only ten feet long will strike and discharge its fire on the punch at two or three inches distance, an electrified cloud of perhaps ten thousand acres may strike and discharge on the earth at a proportionately greater distance. The horizontal motion of the scales over the floor, may represent the motion of the clouds over the earth; and the erect iron punch, a hill or high building; and then we see how electrified clouds passing over hills or high buildings at too great a height to strike, may be attracted lower till within their striking distance. And, lastly, if a needle fixed on the punch with its point upright, or even on the floor below the punch, will draw the fire from the scale silently at a much greater than the striking distance, and so prevent its descending towards the punch; or if in its course it would have come nigh enough to strike, yet being first deprived of its fire it cannot, and the punch is thereby secured from the stroke; I say, if these things are so, may not the knowledge of this power of points be of use to mankind, in preserving houses, churches, ships, &c., from the stroke of lightning, by directing us to fix, on the highest parts of those edifices, upright rods of iron made sharp as a needle, and gilt to prevent rusting, and from the foot of those rods a wire down the outside of the building into the ground, or down round one of the shrouds of a ship, and down her side till it reaches the water? Would not these pointed rods probably draw the electrical fire silently out of a cloud before it came nigh enough to strike, and thereby secure us from that most sudden and terrible mischief?

To determine the question, whether the clouds that contain lightning are electrified or not, I would propose an experiment to be tried where it may be done conveniently. On the top of some high tower or steeple, place a kind of sentry-box, (as in Fig. 9,) big enough to contain a man and an electrical stand. From the middle of the stand let an iron rod rise and pass bending out of the door, and then upright twenty or thirty feet, pointed very sharp at the end. If the electrical stand be kept clean and dry, a man standing on it, when such clouds are passing low, might be electrified and afford sparks, the rod drawing fire to him from a cloud. If any danger to the man should be apprehended (though I think there would be none), let him stand on the floor of his box, and now and then bring near to the rod the loop of a wire that has one end fastened to the leads, he holding it by a wax handle; so the sparks, if the rod is electrified, will strike from the rod to the wire, and not affect him.

THE KITE EXPERIMENT

A history of Franklin's results in electricity was drawn up by Dr. Stuber, who resided in Philadelphia, and who seems to have written from minute and accurate information.

"His observations," says Dr. Stuber, "he communicated, in a series of letters, to his friend Collinson, the first of which is dated March 28th, 1747. In these he shows the power of points in drawing and throwing off the electrical matter, which had hitherto escaped the notice of electricians. He also made the grand discovery of a plus and minus, or of a positive and negative state of electricity. We give him the honor of this, without hesitation; although the English have claimed it for their countryman, Dr. Watson. Watson's paper is dated January 21st, 1748; Franklin's July 11th, 1747, several months prior. Shortly after, Franklin, from his principles of the plus and minus state, explained, in a satisfactory manner, the phenomena of the Leyden phial, first observed by Mr. Cuneus, or by Professor Muschenbroeck, of Leyden, which had much perplexed philosophers. He showed clearly, that, when charged, the bottle contained no more electricity than before, but that as much was taken from one side as was thrown on the other; and that, to discharge it, nothing was necessary but to produce a communication between the two sides, by which the equilibrium might be restored, and that then no signs of electricity would remain. He afterwards demonstrated, by experiments, that the electricity did not reside in the coating, as had been supposed, but in the pores of the glass itself. After a phial was charged, he removed the coating, and found that upon applying a new coating the shock might still be received. In the year 1749, he first suggested his idea of explaining the phenomena of thunder-gusts, and of the aurora borealis, upon electrical principles. He points out many particulars in which lightning and electricity agree; and he adduces many facts, and reasonings from facts, in support of his positions.

"In the same year, he conceived the astonishingly bold and grand idea of ascertaining the truth of his doctrine, by actually drawing down the lightning, by means of sharp-pointed iron rods, raised into the region of the clouds. Even in this uncertain state, his passion to be useful to mankind displayed itself in a powerful manner. Admitting the identity of electricity and lightning, and knowing the power of points in repelling bodies charged with electricity, and in conducting their fire silently and imperceptibly, he suggested the idea of securing houses, ships, &c., from being damaged by lightning, by erecting pointed rods, that should rise some feet above the most elevated part, and descend some feet into the ground or the water. The effect of these, he concluded, would be either to prevent a stroke by repelling the cloud beyond the striking distance, or by drawing off the electrical fire which it contained; or, if they could not effect this, they would at least conduct the electric matter to the earth, without any injury to the building.

"It was not until the summer of 1752, that he was enabled to complete his grand and unparalleled discovery by experiment. The plan which he had originally proposed was, to erect, on some high tower or other elevated place, a sentry-box, from which should rise a pointed iron rod, insulated by being fixed in a cake of resin. Electrified clouds passing over this would, he conceived, impart to it a portion of their electricity, which would be rendered evident to the senses by sparks being emitted, when a key, the knuckle, or other conductor was presented to it. Philadelphia at this time afforded no opportunity of trying an experiment of this kind. While Franklin was waiting for the erection of a spire, it occurred to him that he might have more ready access to the region of clouds by means of a common kite. He prepared one by fastening two cross sticks to a silk handkerchief, which would not suffer so much from the rain as paper. To the upright stick was affixed an iron point. The string was, as usual, of hemp, except the lower end, which was silk. Where the hempen string terminated, a key was fastened. With this apparatus, on the appearance of a thunder-gust approaching, he went out into the commons, accompanied by his son, to whom alone he communicated his intentions, well knowing the ridicule, which, too generally for the interest of science, awaits unsuccessful experiments in philosophy. He placed himself under a shed, to avoid the rain; his kite was raised, a thunder-cloud passed over it, no sign of electricity appeared. He almost despaired of success, when suddenly he observed the loose fibres of his string to move towards an erect position. He now presented his knuckle to the key, and received a strong spark. How exquisite must his sensations have been at this moment! On this experiment depended the fate of his theory. If he succeeded, his name would rank high among those who had improved science; if he failed, he must inevitably be subjected to the derision of mankind, or, what is worse, their pity, as a well-meaning man, but a weak, silly projector. The anxiety, with which he looked for the result of his experiment, may be easily conceived. Doubts and despair had begun to prevail, when the fact was ascertained, in so clear a manner, that even the most incredulous could no longer withhold their assent. Repeated sparks were drawn from the key, a phial was charged, a shock given, and all the experiments made which are usually performed with electricity."

BLACK

Joseph Black was born in 1728 at Bordeaux, France. He was educated at Belfast and at the University of Glasgow. In 1754 he took his M. D. degree at Edinburgh.

He had already showed that the alkalies were formed not by their absorbing the mythical phlogiston, but by having as a component "fixed air," i. e., carbonic acid gas. This was found out in 1752. In his work he constantly weighed his materials, thus antedating Lavoisier in the idea of the permanency of matter. His discovery that there was an air-like substance that was not air had a wonderful influence.

In 1753 he was made a lecturer on chemistry at Glasgow, and in 1766 succeeded Cullen at Edinburgh.

In 1763 he discovered the principle of latent heat—that heat combines with a substance to change it from a solid to a fluid or from a liquid to a gas, and that this heat remains inactive—latent—in the new condition. This principle is the basis of the steam engine, artificial ice and freezing, and the like, and has been of immense practical importance.

Black died in 1799.

THE DISCOVERY OF CARBONIC ACID GAS, "FIXED AIR"

Hoffman, in one of his observations, gives the history of a powder called *Magnesia Alba,* which had been long used, and esteemed as a mild and tasteless purgative; but the method of preparing it was not generally known before he made it public.

It was originally obtained from a liquor called the *Mother of nitre,* which is produced in the following manner:

Salt-petre is separated from the brine which first affords it, or from the water with which it is washed out of nitrous earths, by the process commonly used in crystallizing salts. In this process, the brine is gradually diminished, and at length reduced to a small quantity of an unctuous bitter saline liquor, affording no more salt-petre by evaporation, but, if urged with a brisk fire, drying up into a confused mass, which attracts water strongly, and becomes fluid again when exposed to the open air.

To this liquor the workmen have given the name of the *Mother of nitre*; and Hoffman, finding it composed of the magnesia united to an acid, obtained a separation of these, either by exposing the compound to a strong fire, in which the acid was dissipated, and the magnesia remained behind, or by the addition of an alkali, which attracted the acid to itself: and this last method he recommends as the best. He likewise makes an inquiry into the nature and virtues of the powder thus prepared; and observes, that it is an absorbent earth, which joins readily with all acids, and must necessarily destroy any acidity it meets in the stomach; but that its purgative power is uncertain, for sometimes it has not the least effect of that kind. As it is a mere insipid earth, he rationally concludes it to be a purgative only when converted into a sort of neutral salt by an acid in the stomach, and that its effect is therefore proportional to the quantity of this acid.

Although magnesia appears from this history of it, to be a very innocent medicine; yet, having observed that some hypochondriacs, who used it frequently, were subject to flatulencies and spasms, he seems to have suspected it of some noxious quality. The circumstances, however, which gave rise to his suspicion, may very possibly have proceeded from the imprudence of his patients; who, trusting too much to magnesia (which is properly a palliative in that disease) and neglecting the assistance of other remedies, allowed their disorder to increase upon them. It may, indeed, be alleged that magnesia, as a purgative, is not the most eligible medicine for such constitutions, as they agree best with those that strengthen, stimulate, and warm; which the saline purges, commonly used, are not observed to do. But there seems at least to be no objection to its use, when children are troubled with an acid in their stomach: for, gentle purging, in this case, is very proper; and it is often more conveniently procured by means of magnesia, than of any other medicine, on account of its being entirely insipid.

The above-mentioned Author, observing, some time after, that a bitter saline liquor, similar to that obtained from the brine of salt-petre, was likewise produced by the evaporation of those waters which contain common salt, had the curiosity to try if this would also yield a magnesia. The experiment succeeded: And he thus found out another process for obtaining this powder; and at the same time assured himself, by experiments, that the product from both was exactly the same.

My curiosity led me, some time ago, to inquire more particularly into the nature of magnesia, and especially to compare its properties with those of the other absorbent earths, of which there plainly appeared to me to be very different kinds, although commonly confounded together under one name. I was indeed led to this examination of the absorbent earths, partly by the hope of discovering a new sort of lime and lime-water, which might possibly be a more powerful solvent of the stone, than that commonly used; but was disappointed in my expectations.

I have had no opportunity of seeing Hoffman's first magnesia, or the liquor from which it is prepared, and have therefore been obliged to make my experiments upon the second.

In order to prepare it, I at first employed the bitter saline liquor called *bittern*, which remains in the pans after the evaporation of sea-water. But as that liquor is not always easily procured, I afterwards made use of a salt called Epsom salt, which is separated from the bittern by crystallization, and is evidently composed of magnesia and the vitriolic acid.

There is likewise a spurious kind of Glauber salt, which yields plenty of magnesia, and seems to be no other than Epsom salt, of sea-water reduced to crystals of a larger size. And common salt also affords a small quantity of this powder; because, being separated from the bittern by one hasty crystallization only, it necessarily contains a portion of that liquor.

Those who would prepare a magnesia from Epsom salt, may use the following process:

Dissolve equal quantities of Epsom salt, and of pearl ashes, separately, in a sufficient quantity of water; purify each solution from its dregs, and mix them accurately together by violent agitation. Then make them just to boil over a brisk fire.

Add now to the mixture, three or four times its quantity of hot water; after a little agitation, allow the magnesia to settle to the bottom, and decant off as much of the water as possible. Pour on the same quantity of cold water; and, after settling, decant it off in the same manner. Repeat this washing with the cold water ten or twelve times, or even oftener, if the magnesia be required perfectly pure for chemical experiments.

When it is sufficiently washed, the water may be strained and squeezed from it in a linen cloth; for very little of the magnesia passes through.

The alkali in the mixture, uniting with the acid, separates it from the magnesia; which, not being of itself soluble in water, must consequently appear immediately under a solid form. But the powder which thus appears is not entirely magnesia; part of it, is the neutral salt formed from the union of the acid and alkali. This neutral salt is found, upon examination, to agree in all respects with vitriolated tartar, and requires a large quantity of hot water to dissolve it. As much of it is therefore dissolved as the water can take up; the rest is dispersed through the mixture, in the form of a powder. Hence the necessity of washing the magnesia with so much trouble; for the first effusion of hot water is intended to dissolve the whole of the salt, and the subsequent additions of cold water to wash away this solution.

The caution given, of boiling the mixture, is not unnecessary: if it be neglected, the whole of the magnesia is not accurately separated at once; and, by allowing it to rest for some time, that powder concretes into minute grains, which, when viewed with the microscope, appear to be assemblages of needles diverging from a point. This happens more especially when the solution of the Epsom salt, and of the alkali, are diluted with too much water before they are mixed together. Thus, if a dram of Epsom salt, and of salt of tartar, be dissolved each in four ounces of water, and be mixed, and then allowed to rest three or four days, the whole of the magnesia will be formed into these grains. Or, if we filtrate the mixture soon after it is made, and heat the clear liquor which passes through, it will become turbid, and deposit a magnesia.

An ounce of magnesia was exposed in a crucible, for about an hour, to such a heat as is sufficient to melt copper. When taken out, it weighed three drams and one scruple, or had lost 7-12 of its former weight.

I repeated, with the magnesia prepared in this manner, most of those experiments I had already made upon it before calcination, and the result was as follows:—

It dissolves in all the acids, and with these composes salts exactly similar to those described in the first set of experiments: But, what is particularly to be remarked, it is dissolved without any the least degree of effervescence.

It slowly precipitates the corrosive sublimate of mercury, in the form of a black powder.

It separates the volatile alkali in salt-ammoniac from the acid, when it is mixed with a warm solution of that salt. But it does not separate an acid from a calcareous earth, nor does it introduce the least change upon lime-water.

Lastly, when a dram of it is digested with an ounce of water in a bottle for some hours, it does not make any the least change in the water. The magnesia, when dried, is found to have gained ten grains; but it neither effervesces with acids, nor does it sensibly affect lime-water.

Observing magnesia to lose such a remarkable proportion of its weight in the fire, my next attempts were directed to the investigation of this volatile part; and, among other experiments, the following seemed to throw some light upon it:—

Three ounces of magnesia were distilled in a glass retort and receiver, the fire being gradually increased until the magnesia was obscurely red hot. When all was cool, I found only five drams of a whitish water in the receiver, which had a faint smell of the spirit of hartshorn, gave a green colour to the juice of violets, and rendered the solutions of corrosive sublimate, and of silver, very slightly turbid. But it did not sensibly effervesce with acids.

The magnesia, when taken out of the retort, weighed an ounce, three drams, and thirty grains, or had lost more than half of its weight. It still effervesced pretty briskly with acids, though not so strongly as before this operation.

The fire should have been raised here to the degree requisite for the perfect calcination of magnesia. But, even from this imperfect experiment, it is evident, that, of the volatile parts contained in that powder, a small proportion only is water; the rest cannot, it seems, be retained in vessels, under a visible form. Chemists have often observed, in their distillations, that part of a body has vanished from their senses, notwithstanding the utmost care to retain it; and they have always found, upon further inquiry, that subtle part to be air, which having been imprisoned in the body, under a solid form, was set free, and rendered fluid and elastic by the fire. We may therefore safely conclude, that the volatile matter lost in the calcination of magnesia, is mostly air; and hence the calcined magnesia does not emit air, or make an effervescence when mixed with acids.

The water, from its properties, seems to contain a small portion of volatile alkali, which was probably formed from the earth, air and water, or from some of these combined together; and perhaps also from a small quantity of inflammable matter, which adhered accidentally to the magnesia. Whenever chemists meet with this salt, they are inclined to ascribe its origin to some animal or putrid vegetable substance; and this they have always done, when they obtained it from the calcareous earths, all of which afford a small quantity of it. There is, however, no doubt, that it can sometimes be produced independently of any such mixture, since many fresh vegetables, and tartar, afford a considerable quantity of it. And how can it, in the present instance, be supposed, that any animal or vegetable matter adhered to the magnesia, while it was dissolved by an acid, separated from this by an alkali, and washed with so much water?

Two drams of magnesia were calcined in a cucible, in the manner described above, and thus reduced to two scruples and twelve grains. This calcined magnesia was dissolved in a sufficient quantity of spirit of vitriol, and then again separated from the acid by the addition of an alkali, of which a large quantity is necessary for this purpose. The magnesia being very well washed and dried, weighed one dram and fifty grains. It effervesced violently, or emitted a large quantity of air, when thrown into acids; formed a red powder, when mixed with a solution of sublimate; separated the calcareous earths from an acid, and sweetened lime-water; and had thus recovered all those properties which it had but just now lost by calcination. Nor had it only recovered its original properties, but acquired besides an addition of weight, nearly equal to what had been lost in the fire; and as it is found to effervesce with acids, part of the addition must certainly be air.

This air seems to have been furnished by the alkali, from which it was separated by the acid; for Dr. Hales has clearly proved, that alkaline salts contain a large quantity of fixed air, which they emit in great abundance when joined to a pure acid. In the present case, the alkali is really joined to an acid, but without any visible emission of air; and yet the air is not retained in it; for the neutral salt, into which it is converted, is the same in quantity, and in every other respect, as if the acid employed had not been previously saturated with magnesia, but offered to the alkali in its pure state, and had driven the air out of it in their conflict. It seems therefore evident, that the air was forced from the alkali by the acid, and lodged itself in the magnesia.

These considerations led me to try a few experiments, whereby I might know what quantity of air is expelled from an alkali, or from magnesia, by acids.

Two drams of a pure fixed alkaline salt, and an ounce of water, were put into a Florentine flask, which, together with its contents, weighed two ounces and two drams. Some oil of vitriol diluted with water was dropped in, until the salt was exactly saturated; which it was found to be, when two drams, two scruples and three grains of this acid had been added. The phial with its contents now weighed two ounces, four drams and fifteen grains. One scruple, therefore, and eight grains, were lost during the ebullition; of which a trifling portion may be water, or something of the same kind; the rest is air.

PRIESTLEY

JOSEPH PRIESTLEY was born March 13, 1733, in Yorkshire, England. Until twenty years old he studied under neighboring ministers, and learned the classics and Hebrew, besides picking up French, Italian, and German without assistance. Later he was sent to Daventry to a non-conformist academy, and studied Chaldee, Syriac, and Arabic, together with mathematics, physics, philosophy, and the like. At twenty-two he took charge of a small church at Needham. In 1761 he was appointed classical tutor at Warrington academy, and about this time became interested in natural science. He joined the Royal Society in 1766, and the next year took the Mill Hill chapel at Leeds. In 1774 he discovered oxygen, called by him "dephlogisticated air." This is the most definite of his results and the great importance of this gas made its discovery have a tremendous influence. In addition, however, he was either the first or among the first to prepare nitric oxide, hydrochloric acid, etc.

As a theologian, Priestley was very liberal and came to believe in the rule of law everywhere throughout the universe. In politics he was a partisan of republicanism. On account of these views, his house was burned in 1791 by a mob and all his papers and other valuable possessions destroyed. From 1794 to his death in 1804 he found a pleasant refuge in Northumberland, Pennsylvania.

THE DISCOVERY OF OXYGEN

Presently, after my return from abroad, I went to work upon the *mercurius calcinatus*, which I had procured from Mr. Cadet; and, with a very moderate degree of heat, I got from about one-fourth of an ounce of it, an ounce-measure of air, which I observed to be not readily imbibed, either by the substance itself from which it had been expelled (for I suffered them to continue a long time together before I transferred the air to any other place) or by water, in which I suffered this air to stand a considerable time before I made any experiment upon it.

In this air, as I had expected, a candle burned with a vivid flame; but what I observed new at this time (November 19), and which surprised me no less than the fact I had discovered before, was, that, whereas a few moments agitation in water will deprive the modified nitrous air of its property of admitting a candle to burn in it; yet, after more than ten times as much agitation as would be sufficient to produce this alteration in the nitrous air, no sensible change was produced in this. A candle still burned in it with a strong flame; and it did not, in the least, diminish common air, which I have observed that nitrous air, in this state, in some measure does.

But I was much more surprised, when, after two days, in which this air had continued in contact with water (by which it was diminished about one-twentieth of its bulk) I agitated it violently in water about five minutes, and found that a candle still burned in it as well as in common air. The same degree of agitation would have made phlogisticated nitrous air fit for respiration indeed, but it would certainly have extinguished a candle.

These facts fully convinced me, that there must be a very material difference between the constitution of the air from *mercurius calcinatus*, and that of phlogisticated nitrous air, notwithstanding their resemblance in some particulars. But though I did not doubt that the air from *mercurius calcinatus* was fit for respiration, after being agitated in water, as every kind of air without exception, on which I had tried the experiment, had been, I still did not suspect that it was respirable in the first instance; so far was I from having any idea of this air being, what it really was, much superior, in this respect, to the air of the atmosphere.

In this ignorance of the real nature of this kind of air, I continued from this time (November) to the 1st of March following; having, in the meantime, been intent upon my experiments on the vitriolic acid air above recited, and the various modifications of air produced by spirit of nitre, an account of which will follow. But in the course of this month, I not only ascertained the nature of this kind of air, though very gradually, but was led to it by the complete discovery of the constitution of the air we breathe.

Till this 1st of March, 1775, I had so little suspicion of the air from *mercurius calcinatus,* &c., being wholesome, that I had not even thought of applying it to the test of nitrous air; but thinking (as my reader must imagine I frequently must have done) on the candle burning in it after long agitation in water, it occurred to me at last to make the experiment; and putting one measure of nitrous air to two measures of this air, I found, not only that it was diminished, but that it was diminished quite as much as common air, and that the redness of the mixture was likewise equal to that of a similar mixture of nitrous and common air.

After this I had no doubt but that the air from *mercurius calcinatus* was fit for respiration, and that it had all the other properties of genuine common air. But I did not take notice of what I might have observed, if I had not been so fully possessed by the notion of there being no air better than common air, that the redness was really deeper, and the diminution something greater than common air would have admitted.

Moreover, this advance in the way of truth, in reality, threw me back into error, making me give up the hypothesis I had first formed, viz. that the *mercurius calcinatus* had extracted spirit of nitre from the air; for I now concluded, that all the constituent parts of the air were equally, and in their proper proportion, imbibed in the preparation of this substance, and also in the process of making red lead. For at the same time that I made the above mentioned experiment on the air from *mercurius calcinatus,* I likewise observed that the air which I had extracted from red lead, after the fixed air was washed out of it, was of the same nature, being diminished by nitrous air like common air: but, at the same time, I was puzzled to find that air from the red precipitate was diminished in the same manner, though the process for making this substance is quite different from that of making the two others. But to this circumstance I happened not to give much attention.

I wish my reader be not quite tired with the frequent repetition of the word surprise, and others of similar import; but I must go on in that style a little longer. For the next day I was more surprised than ever

I had been before, with finding that, after the above-mentioned mixture of nitrous air and the air from *mercurius calcinatus,* had stood all night, (in which time the whole diminution must have taken place; and, consequently, had it been common air, it must have been made perfectly noxious, and entirely unfit for respiration or inflammation) a candle burned in it, and even better than in common air.

I cannot, at this distance of time, recollect what it was that I had in view in making this experiment; but I know I had no expectation of the real issue of it. Having acquired a considerable degree of readiness in making experiments of this kind, a very slight and evanescent motive would be sufficient to induce me to do it. If, however, I had not happened, for some other purpose, to have had a lighted candle before me, I should probably never have made the trial; and the whole train of my future experiments relating to this kind of air might have been prevented.

Still, however, having no conception of the real cause of this phenomenon, I considered it as something very extraordinary; but as a property that was peculiar to air that was extracted from these substances, and adventitious; and I always spoke of the air to my acquaintance as being substantially the same thing with common air. I particularly remember my telling Dr. Price, that I was myself perfectly satisfied of its being common air, as it appeared to be so by the test of nitrous air; though, for the satisfaction of others, I wanted a mouse to make the proof quite complete.

On the 8th of this month I procured a mouse, and put it into a glass vessel, containing two ounce-measures of the air from *mercurius calcinatus.* Had it been common air, a full-grown mouse, as this was, would have lived in it about a quarter of an hour. In this air, however, my mouse lived a full half hour; and though it was taken out seemingly dead, it appeared to have been only exceedingly chilled; for, upon being held to fire, it presently revived, and appeared not to have received any harm from the experiment.

By this I was confirmed in my conclusion, that the air extracted from *mercurius calcinatus,* &c., was, at least, as good as common air; but I did not certainly conclude that it was any better; because, though one mouse would live only a quarter of an hour in a given quantity of air, I knew it was not impossible but that another mouse might have lived in it half an hour; so little accuracy is there in this method of ascertaining the goodness of air; and indeed I have never had recourse to it for my own satisfaction, since the discovery of that most ready, accurate, and elegant test that nitrous air furnishes. But in this case I had a view to publishing the most generally satisfactory account of my experiments that the nature of the thing would admit of.

This experiment with the mouse, when I had reflected upon it some time, gave me so much suspicion that the air into which I had put it was better than common air, that I was induced, the day after, to apply the test of nitrous air to a small part of that very quantity of air which the mouse had breathed so long; so that, had it been common air, I was satisfied it must have been very nearly, if not altogether, as noxious as possible, so as not to be affected by nitrous air; when, to my surprise again, I found that though it had been breathed so long, it was still better than common air. For after mixing it with nitrous air, in the usual proportion of two to one, it was diminished in the proportion of four and one-half to three and one-half; that is, the nitrous air had made it two-ninths less than before, and this in a very short space of time; whereas I had never found that, in the longest time, any common air was reduced more than one-fifth of its bulk by any proportion of nitrous air, nor more than one-fourth by any phlogistic process whatever. Thinking of this extraordinary fact upon my pillow, the next morning I put another measure of nitrous air to the same mixture, and, to my utter astonishment, found that it was farther diminished to almost one-half of its original quantity. I then put a third measure to it; but this did not diminish it any farther; but, however, left it one measure less than it was even after the mouse had been taken out of it.

Being now fully satisfied that this air, even after the mouse had breathed it half an hour, was much better than common air; and having a quantity of it still left, sufficient for the experiment, viz. an ounce-measure and a half, I put the mouse into it; when I observed that it seemed to feel no shock upon being put into it, evident signs of which would have been visible, if the air had not been very wholesome; but that it remained perfectly at its ease another full half hour, when I took it out quite lively and vigorous. Measuring the air the next day, I found it to be reduced from one and one-half to two-thirds of an ounce-measure. And after this, if I remember well (for in my register of the day I only find it noted, that it was considerably diminished by nitrous air), it was nearly as good as common air. It was evident, indeed, from the mouse having been taken out quite vigorous, that the air could not have been rendered very noxious.

For my farther satisfaction I procured another mouse, and putting it into less than two ounce-measures of air extracted from *mercurius calcinatus* and air from red precipitate (which, having found them to be of the same quality, I had mixed together) it lived three-quarters of an hour. But not having had the precaution to set the vessel in a warm place, I suspect that the mouse died of cold. However, as it had lived three times as long as it could probably have lived in the same quantity of common air, and I did not expect much accuracy from this kind of a test, I did not think it necessary to make any more experiments with mice.

Being now fully satisfied of the superior goodness of this kind of air, I proceeded to measure that degree of purity, with as much accuracy as I could, by the test of nitrous air; and I began with putting one measure of nitrous air to two measures of this air, as if I had been examining common air; and now I observed that the diminution was evidently greater than common air would have suffered by the same treatment. A second measure of nitrous air reduced it to two-thirds of its original quantity, and a third measure to one-half. Suspecting that the diminution could not proceed much farther, I then added only half a measure of nitrous air, by which it was diminished still more; but not much, and another half measure made it more than half of its original quantity; so that, in this case, two measures of this air took more than two measures of nitrous air, and yet remained less than half of what it was. Five measures brought it pretty exactly to its original dimensions.

At the same time, air from the red precipitate was diminished in the same proportion as that from *mercurius calcinatus*, five measures of nitrous air being received by two measures of this without any increase of dimensions. Now as common air takes about one-half of its bulk of nitrous air, before it begins to receive any addition to its dimensions from more nitrous air, and this air took more than four half-measures before it ceased to be diminished by more nitrous air, and even five half-measures made no addition to its original dimensions, I conclude that it was between four and five times as good as common air. It will be seen that I have since procured air better than this, even between five and six times as good as the best common air that I have ever met with.

SCHEELE

Karl Wilhelm Scheele was born at Stralsund, Pomerania, then a part of Sweden, on December 19, 1742. His father was a merchant. In school young Karl early showed a taste for pharmacy and was apprenticed to an apothecary in Gothenburg.

The rest of his life, though lived in various places, was occupied with his chemical experiments. In fact, he was one of the most indefatigable experimenters in the history of the science. In 1777 he published his treatise on "Air and Fire," in which he discovered independently of the English chemists the double composition of air. He died in 1786.

CHEMICAL TREATISE ON AIR AND FIRE

1. It is the object and chief business of chemistry to skilfully separate substances into their constituents, to discover their properties, and to compound them in different ways.

How difficult it is, however, to carry out such operations with the greatest accuracy, can only be unknown to one who either has never undertaken this occupation, or at least has not done so with sufficient attention.

2. Hitherto chemical investigators are not agreed as to how many elements or fundamental materials compose all substances. In fact this is one of the most difficult problems; some indeed hold that there remains no further hope of searching out the elements of substances. Poor comfort for those who feel their greatest pleasure in the investigation of natural things! Far is he mistaken, who endeavours to confine chemistry, this noble science, within such narrow bounds! Others believe that earth and phlogiston are the things from which all material nature has derived its origin. The majority seem completely attached to the peripatetic elements.

3. I must admit that I have bestowed no little trouble upon this

matter in order to obtain a clear conception of it. One may reasonably be amazed at the numerous ideas and conjectures which authors have recorded on the subject, especially when they give a decision respecting the phenomenon of fire; and this very matter was of the greatest importance to me. I perceived the necessity of a knowledge of fire, because without this it is not possible to make any experiment; and without fire and heat it is not possible to make use of the action of any solvent. I began accordingly to put aside all explanations of fire; I undertook a multitude of experiments in order to fathom this beautiful phenomenon as fully as possible. I soon found, however, that one could not form any true judgment regarding the phenomena which fire presents, without a knowledge of the air. I saw, after carrying out a series of experiments, that air really enters into the mixture of fire, and with it forms a constituent of flame and of sparks. I learned accordingly that a treatise like this, on fire, could not be drawn up with proper completeness without taking the air also into consideration.

4. Air is that fluid invisible substance which we continually breathe, which surrounds the whole surface of the earth, is very elastic, and possesses weight. It is always filled with an astonishing quantity of all kinds of exhalations, which are so finely subdivided in it that they are scarcely visible even in the sun's rays. Water vapours always have the preponderance amongst these foreign particles. The air, however, is also mixed with another elastic substance resembling air, which differs from it in numerous properties, and is, with good reason, called aerial acid by Professor Bergman. It owes its presence to organised bodies, destroyed by putrefaction or combustion.

5. Nothing has given philosophers more trouble for some years than just this delicate acid or so-called fixed air. Indeed it is not surprising that the conclusions which one draws from the properties of this elastic acid are not favourable to all who are prejudiced by previously conceived opinions. These defenders of the Paracelsian doctrine believe that the air is in itself unalterable; and, with Hales, that it really unites with substances thereby losing its elasticity; but that it regains its original nature as soon as it is driven out of these by fire or fermentation. But since they see that the air so produced is endowed with properties quite different from common air, they conclude, without experimental proofs, that this air has united with foreign materials, and that it must be purified from these admixed foreign particles by agitation and filtration with various liquids. I believe that there would be no hesitation in

accepting this opinion, if one could only demonstrate clearly by experiments that a given quantity of air is capable of being completely converted into fixed or other kind of air by the admixture of foreign materials; but since this has not been done, I hope I do not err if I assume as many kinds of air as experiment reveals to me. For when I have collected an elastic fluid, and observe concerning it that its expansive power is increased by heat and diminished by cold, while it still uniformly retains its elastic fluidity, but also discover in it properties and behavior different from those of common air, then I consider myself justified in believing that this is a peculiar kind of air. I say that air thus collected must retain its elasticity even in the greatest cold, because otherwise an innumerable multitude of varieties of air would have to be assumed, since it is very probable that all substances can be converted by excessive heat into a vapour resembling air.

6. Substances which are subjected to putrefaction or to destruction by means of fire diminish, and at the same time consume, a part of the air; sometimes it happens that they perceptibly increase the bulk of the air, and sometimes finally that they neither increase nor diminish a given quantity of air—phenomena which are certainly remarkable. Conjectures can here determine nothing with certainty, at least they can only bring small satisfaction to a chemical philosopher, who must have his proofs in his hands. Who does not see the necessity of making experiments in this case, in order to obtain light concerning this secret of nature?

7. General properties of ordinary air.

(1.) Fire must burn for a certain time in a given quantity of air. (2.) If, so far as can be seen, this fire does not produce during combustion any fluid resembling air, then, after the fire has gone out of itself, the quantity of air must be diminished between a third and a fourth part. (3.) It must not unite with common water. (4.) All kinds of animals must live for a certain time in a confined quantity of air. (5.) Seeds, as for example peas, in a given quantity of similarly confined air, must strike roots and attain a certain height with the aid of some water and of a moderate heat.

Consequently, when I have a fluid resembling air in its external appearance, and find that it has not the properties mentioned, even when only one of them is wanting, I feel convinced that it is not ordinary air.

8. Air must be composed of elastic fluids of two kinds.

First Experiment.—I dissolved one ounce of alkaline liver of sulphur in eight ounces of water; I poured four ounces of this solution into an empty bottle capable of holding 24 ounces of water, and closed it most securely with a cork; I then inverted the bottle and placed the neck in a small vessel with water; in this position I allowed it to stand for fourteen days. During this time the solution had lost a part of its red colour and had also deposited some sulphur: afterwards I took the bottle and held it in the same position in a larger vessel with water, so that the mouth was under and the bottom above the water-level, and withdrew the cork under the water; immediately water rose with violence into the bottle. I closed the bottle again, removed it from the water, and weighed the fluid which it contained. There were 10 ounces. After subtracting from this the four ounces of solution of sulphur there remain six ounces, consequently it is apparent from this experiment that of 20 parts of air six parts have been lost in 14 days.

9. Second Experiment.—(a) I repeated the preceding experiment with the same quantity of liver of sulphur, but with this difference that I only allowed the bottle to stand a week tightly closed. I then found that of 20 parts of air only 4 had been lost. (b) On another occasion I allowed the very same bottle to stand four months; the solution still possessed a somewhat dark yellow colour. But no more air had been lost than in the first experiment, that is to say six parts.

10. Third Experiment.—I mixed two ounces of caustic ley, which was prepared from alkali of tartar and unslaked lime and did not precipitate lime-water, with half an ounce of the preceding solution of sulphur, which likewise did not precipitate lime-water. This mixture had a yellow colour. I poured it into the same bottle, and after this had stood fourteen days, well closed, I found the mixture entirely without colour and also without precipitate. I was enabled to conclude that the air in this bottle had likewise diminished, from the fact that air rushed into the bottle with a hissing sound after I had made a small hole in the cork.

11. Fourth Experiment.—(a.) I took four ounces of a solution of sulphur in lime water; I poured this solution into a bottle and closed it tightly. After 14 days the yellow colour had disappeared, and of 20 parts of air 4 parts had been lost. The solution contained no sulphur, but had allowed a precipitate to fall which was chiefly gypsum. (b.) Volatile liver of sulphur likewise diminishes the bulk of air. (c) Sulphur, however, and volatile spirit of sulphur, undergo no alteration in it.

12. Fifth Experiment.—I hung up over burning sulphur, linen rags which were dipped in a solution of alkali of tartar. After the alkali was saturated with the volatile acid, I placed the rags in a flask, and closed the mouth most carefully with a wet bladder. After three weeks had elapsed I found the bladder strongly pressed down; I inverted the flask, held its mouth in water and made a hole in the bladder; thereupon water rose with violence into the flask and filled the fourth part.

13. Sixth Experiment.—I collected in the bladder the nitrous acid which arises on the dissolution of the metals in nitrous acid, and after I had tied the bladder tightly I laid it in a flask and secured the mouth very carefully with a wet bladder. The nitrous air gradually lost its elasticity, the bladder collapsed, and became yellow as if corroded by *aqua fortis*. After 14 days I made a hole in the bladder tied over the flask, having previously held it, inverted, under water; the water rose rapidly into the flask, and it remained only two-thirds empty.

14. Seventh Experiment.—(a.) I immersed the mouth of a flask in a vessel with oil of turpentine. The oil rose in the flask a few lines every day. After the lapse of 14 days the fourth part of the flask was filled with it. I allowed it to stand for three weeks longer, but the oil did not rise higher. All those oils which dry in the air, and become converted into resinous substances, possess this property. Oil of turpentine, however, and linseed oil rise up sooner if the flask is previously rinsed out with a concentrated sharp ley. (b.) I poured two ounces of colourless and transparent animal oil of Dippel into a bottle and closed it very tightly; after the expiration of two months the oil was thick and black. I then held the bottle, inverted, under water and drew out the cork; the bottle immediately became one-fourth filled with water.

15. Eighth Experiment.—(a.) I dissolved two ounces of vitriol of iron in thirty-two ounces of water, and precipitated this solution with a caustic ley. After the precipitate had settled, I poured away the clear fluid and put the dark green precipitate of iron so obtained, together with the remaining water, into the before-mentioned bottle (§8), and closed it tightly. After 14 days (during which time I shook the bottle frequently, this green calx of iron had acquired the colour of crocus of iron, and of 40 parts of air 12 had been lost. (b.) When iron filings are moistened with some water and preserved for a few weeks in a well closed bottle, a portion of the air is likewise lost. (c.) The solution of iron in vinegar has the same effect upon air. In this case the vinegar permits the dissolved iron to fall out in the form of a yellow crocus, and

becomes completely deprived of this metal. (d.) The solution of copper prepared in closed vessels with spirit of salt likewise diminishes air. In none of the foregoing kinds of air can either a candle burn or the smallest spark glow.

16. It is seen from these experiments that phlogiston, the simple inflammable principle, is present in each of them. It is known that the air strongly attracts to itself the inflammable part of substances and deprives them of it: not only this may be seen from the experiments cited, but it is at the same time evident that on the transference of the inflammable substance to the air a considerable part of the air is lost. But that inflammable substance alone is the cause of this action, is plain from this, that, according to the tenth paragraph, not the least trace of sulphur remains over, since, according to my experiments this colourless ley contains only some vitriolated tartar. The eleventh paragraph likewise shews this. But since sulphur alone, and also the volatile spirit of sulphur, have no effect upon the air (§ 11. c), it is clear that the decomposition of liver of sulphur takes place according to the laws of double affinity—that is to say, that the alkalies and lime attract the vitriolic acid, and the air attracts the phlogiston.

It may also be seen from the above experiments, that a given quantity of air can only unite with, and at the same time saturate, a certain quantity of the inflammable substance: this is evident from the ninth paragraph, letter b. But whether the phlogiston which was lost by the substances was still present in the air left behind in the bottle, or whether the air which was lost had united and fixed itself with the materials such as liver of sulphur, oils, &c., are questions of importance.

From the first view, it would necessarily follow that the inflammable substance possessed the property of depriving the air of part of its elasticity, and that in consequence of this it becomes more closely compressed by the external air. In order now to help myself out of these uncertainties, I formed the opinion that any such air must be specifically heavier than ordinary air, both on account of its containing phlogiston and also of its greater condensation. But how perplexed was I when I saw that a very thin flask which was filled with this air, and most accurately weighed, not only did not counterpoise an equal quantity of ordinary air, but was even somewhat lighter. I then thought that the latter view might be admissible; but in that case it would necessarily follow also that the lost air could be separated again from the materials employed. None of the experiments cited seemed to me capable of shewing this more clearly than that according to the tenth paragraph, because this residuum, as already mentioned, consists of vitriolated tartar and alkali. In order therefore to see whether the lost air had been converted into fixed air, I tried whether the latter shewed itself when some of the caustic ley was poured into lime water; but in vain—no precipitation took place. Indeed, I tried in several ways to obtain the lost air from this alkaline mixture, but as the results were similar to the foregoing, in order to avoid prolixity I shall not cite these experiments. Thus much I see from the experiments mentioned, that the air consists of two fluids, differing from each other, the one of which does not manifest in the least the property of attracting phlogiston, while the other, which composes between the third and the fourth part of the whole mass of the air, is peculiarly disposed to such attraction. But where this latter kind of air has gone to after it has united with the inflammable substance, is a question which must be decided by further experiments, and not by conjectures.

CAVENDISH

Henry Cavendish was born at Nice, Italy, October 10, 1731. He studied at Cambridge, but took no degree there. In 1760 he joined the Royal Society, and his Thursday dinners there were almost his only communication with the world. His large fortune let him devote himself to science.

In 1766 he discovered hydrogen, and some years later, after Priestley had discovered oxygen, Cavendish found that the combination of the two gases produce water. A little later he showed that when nitrogen from the air is present, the result is nitric acid.

These experiments opened up a vast field for research, and have proved of immense importance.

In 1783 he made the guess that heat was a motion rather than a substance. In 1798 he measured the density of the earth by suspending a horizontal bar by a wire, and comparing its horizontal vibrations (or part-swings) with the time of the same vibrations when two large masses of lead were placed at the ends of the case. His result made the earth's density about five and one-half times that of water. Cavendish was also interested in electricity, and believed it to be an elastic fluid.

He died in 1810.

THE COMBINATION OF HYDROGEN AND OXYGEN INTO WATER

In Dr. Priestley's last volume of experiments is related an experiment of Mr. Warltire's, in which it is said that, on firing a mixture of common and inflammable air by electricity in a close copper vessel holding about three pints, a loss of weight was always perceived, on an average about two grains, though the vessel was stopped in such a manner that no air could escape by the explosion. It is also related, that on repeating the experiment in glass vessels, the inside of the glass, though clean and dry before, immediately became dewy; which confirmed an opinion he had long entertained, that common air deposits its moisture by phlogistication. As the latter experiment seemed likely to throw great light on the subject I had in view, I thought it well worth examining more closely. The first experiment also, if there was no mistake in it, would be very extraordinary and curious; but it did not succeed with me; for though the vessel I used held more than Mr. Warltire's, namely, 24,000 grains of water, and though the experiment was repeated several times with different proportions of common and inflammable air, I could never perceive a loss of weight of more than one-fifth of a grain, and commonly none at all. It must be observed, however, that though there were some of the experiments in which it seemed to diminish a little in weight, there were none in which it increased.

In all the experiments, the inside of the glass globe became dewy, as observed by Mr. Warltire; but not the least sooty matter could be perceived. Care was taken in all of them to find how much the air was diminished by the explosion, and to observe its test. The result is as follows, the bulk of the inflammable air being expressed in decimals of the common air:

Common Air.	Inflammable Air.	Diminution.	Air Remaining after the Explosion.	Test of this Air in the First Method.	Standard.
1	1.241	.686	1.555	.055	.0
	1.955	.642	1.423	063	.0
	.706	.647	1.059	.066	.0
	.423	.612	.811	.097	.03
	.331	.476	.855	.339	.27
	.206	.294	.912	.648	.58

In these experiments the inflammable air was procured from zinc, as it was in all my experiments, except where otherwise expressed: but I made two more experiments, to try whether there was any difference between the air from zinc and that from iron, the quantity of inflammable air being the same in both, namely, 0,331 of the common; but I could not find any difference to be depended on between the two kinds of air, either in the diminution which they suffered by the explosion, or the test of the burnt air.

From the fourth experiment it appears, that 423 measures of inflammable air are nearly sufficient to completely phlogisticate 1000 of common air; and that the bulk of the remaining air after the explosion is then very little more than four-fifths of the common air employed; so that as common air cannot be reduced to a much less bulk than that by any method of phlogistication, we may safely conclude, that when they are mixed in this proportion, and exploded, almost all the inflammable air, and about one-fifth part of the common air, lose their elasticity, and are condensed into the dew which lines the glass.

The better to examine the nature of this dew, 500,000 grain measures of inflammable air were burnt with about two and one-half times that quantity of common air, and the burnt air made to pass through a glass cylinder eight feet long and three-quarters of an inch in diameter, in order to deposit the dew. The two airs were conveyed slowly into this cylinder by separate copper pipes, passing through a brass plate which stopped up the end of the cylinder; and as neither inflammable nor common air can burn by themselves, there was no danger of the flame spreading into the magazines from which they were conveyed. Each of these magazines consisted of a large tin vessel, inverted into another vessel just big enough to receive it. The inner vessel communicated with the copper pipe, and the air was forced out of it by pouring water into the outer vessel; and in order that the quantity of common air expelled should be two and one-half times that of the inflammable, the water was let into the outer vessels by two holes in the bottom of the same tin pan, the hole which conveyed the water into that vessel in which the common air was confined being two and one-half times as big as the other.

In trying the experiment, the magazines being first filled with their respective airs, the glass cylinder was taken off, and water let, by the two holes, into the outer vessels, till the airs began to issue from the ends of the copper pipes; they were then set on fire by a candle, and the cylinder put on again in its place. By this means upwards of 135 grains of water were condensed in the cylinder, which had no taste nor smell, and which left no sensible sediment when evaporated to dryness; neither did it yield any pungent smell during evaporation; in short, it seemed pure water.

In my first experiment, the cylinder near that part where the air was fired was a little tinged with sooty matter, but very slightly so; and that little seemed to proceed from the putty with which the apparatus was luted, and which was heated by the flame; for in another experiment, in which it was contrived so that the luting should not be much heated, scarce any sooty tinge could be perceived.

By the experiments with the globe it appeared, that when inflammable and common air are exploded in a proper proportion, almost all the inflammable air, and nearly one-fifth of the common air, lose their elasticity, and are condensed into dew. And by this experiment it appears, that this dew is plain water, and consequently that almost all the inflammable air and about one-fifth of the common air, are turned into pure water.

In order to examine the nature of the matter condensed on firing a mixture of dephlogisticated and inflammable air, I took a glass globe holding 8,800 grain measures, furnished with a brass cock and an apparatus for firing air by electricity. This globe was well exhausted by an air-pump, and then filled with a mixture of inflammable and dephlogisticated air, by shutting the cock, fastening a bent glass tube to its mouth, and letting up the end of it into a glass jar inverted into water, and containing a mixture of 19,500 grain measures of dephlogisticated air, and 37,000 of inflammable; so that, upon opening the cock, some of this mixed air rushed through the bent tube, and filled the globe. The cock was then shut, and the included air fired by electricity, by which means almost all of it lost its elasticity. The cock was then again opened, so as to let in more of the same air, to supply the place of that destroyed by the explosion, which was again fired, and the operation continued till almost the whole of the mixture was let into the globe and exploded. By this means, though the globe held not more than the the sixth part of the mixture, almost the whole of it was exploded therein, without any fresh exhaustion of the globe.

As I was desirous to try the quantity and test of this burnt air, without letting any water into the globe, which would have prevented my examining the nature of the condensed matter, I took a larger globe, furnished also with a stop cock, exhausted it by an air-pump, and screwed it on upon the cock of the former globe; upon which, by opening both cocks, the air rushed out of the smaller globe into the larger, till it became of equal density in both; then, by shutting the cock of the larger globe, unscrewing it again from the former, and opening it under water, I was enabled to find the quantity of the burnt air in it; and consequently, as the proportion which the contents of the two globes bore to each other was known, could tell the quantity of burnt air in the small globe before the communication was made between them. By this means the whole quantity of the burnt air was found to be 2,950 grain measures; its standard was 1,85.

The liquor condensed in the globe, in weight about thirty grains, was sensibly acid to the taste, and by saturation with fixed alkali, and evaporation, yielded near two grains of nitre; so that it consisted of water united to a small quantity of nitrous acid. No sooty matter was deposited in the globe. The dephlogisticated air used in this experiment was procured from red precipitate, that is, from a solution of quicksilver in spirit of nitre distilled till it acquires a red colour.

As it was suspected, that the acid contained in the condensed liquor was no essential part of the dephlogisticated air, but was owing to some acid vapour which came over in making it and had not been absorbed by the water, the experiment was repeated in the same manner, with some more of the same air, which had been previously washed with water, by keeping it a day or two in a bottle with some water, and shaking it frequently; whereas that used in the preceding experiment had never passed through water, except in preparing it. The condensed liquor was still acid.

The experiment was also repeated with dephlogisticated air, procured from red lead by means of oil of vitriol; the liquor condensed was acid, but by an accident I was prevented from determining the nature of the acid.

I also procured some dephlogisticated air from the leaves of plants, in the manner of Doctors Ingenhousz and Priestley, and exploded it with inflammable air as before; the condensed liquor still continued acid, and of the nitrous kind.

In all these experiments the proportion of inflammable air was such, that the burnt air was not much phlogisticated; and it was observed, that the less phlogisticated it was, the more acid was the condensed liquor. I therefore made another experiment, with some more of the same air from plants, in which the proportion of inflammable air was greater, so that the burnt air was almost completely phlogisticated, its standard being 1-10. The condensed liquor was then not at all acid, but seemed pure water; so that it appears, that with this kind of dephlogisticated air, the condensed liquor is not at all acid, when the two airs are mixed in such a proportion that the burnt air is almost completely phlogisticated, but is considerably so when it is not much phlogisticated.

In order to see whether the same thing would obtain with air procured from red precipitate, I made two more experiments with that kind of air, the air in both being taken from the same bottle, and the experiment tried in the same manner, except that the proportions of inflammable air were different. In the first, in which the burnt air was almost completely phlogisticated, the condensed liquor was not at all acid. In the second, in which its standard was 1.86, that is, not much phlogisticated, it was considerably acid; so that with this air, as well as with that from plants, the condensed liquor contains, or is entirely free from, acid, according as the burnt air is less or more phlogisticated; and there can be little doubt but that the same rule obtains with any other kind of dephlogisticated air.

In order to see whether the acid, formed by the explosion of dephlogisticated air obtained by means of the vitriolic acid, would also be of the nitrous kind, I procured some air from turbith mineral, and exploded it with inflammable air, the proportion being such that the burnt air was not much phlogisticated. The condensed liquor manifested an acidity, which appeared, by saturation with a solution of salt of tartar, to be of the nitrous kind; and it was found, by the addition of some *terra ponderosa salita*, to contain little or no vitriolic acid.

When inflammable air was exploded with common air, in such a proportion that the standard of the burnt air was about 4-10, the condensed liquor was not in the least acid. There is no difference, however, in this respect between common air, and dephlogisticated air mixed with phlogisticated in such a proportion as to reduce it to the standard of common air; for some dephlogisticated air from red precipitate, being reduced to this standard by the addition of perfectly phlogisticated air, and then exploded with the same proportion of inflammable air as the common air was in the foregoing experiment, the condensed liquor was not in the least acid.

From the foregoing experiments it appears, that when a mixture of inflammable and dephlogisticated air is exploded in such proportion that the burnt air is not much phlogisticated, the condensed liquor contains a little acid, which is always of the nitrous kind, whatever substance the dephlogisticated air is procured from; but if the proportion be such that the burnt air is almost entirely phlogisticated, the condensed liquor is not at all acid, but seems pure water, without any addition whatever; and as, when they are mixed in that proportion, very little air remains after the explosion, almost the whole being condensed, it follows that almost the whole of the inflammable and dephlogisticated air is converted into pure water. It is not easy, indeed, to determine from these experiments what proportion the burnt air, remaining after the explosions, bore to the dephlogisticated air employed, as neither the small nor the large globe could be perfectly exhausted of air, and there was no saying with exactness what quantity was left in them; but in most of them, after allowing for this uncertainty, the true quantity of burnt air seemed not more than 1-17 of the dephlogisticated air employed, or 1-50 of the mixture. It seems, however, unnecessary to determine this point exactly, as the quantity is so small, that there can be little doubt but that it proceeds only from the impurities mixed with the dephlogisticated and inflammable air, and consequently that, if those airs could be obtained perfectly pure, the whole would be condensed.

With respect to common air, and dephlogisticated air reduced by the addition of phlogisticated air to the standard of common air, the case is different; as the liquor condensed in exploding them with inflammable air, I believe I may say in any proportion, is not at all acid; perhaps because if they are mixed in such a proportion as that the burnt air is not much phlogisticated, the explosion is too weak, and not accompanied with sufficient heat.

All the foregoing experiments, on the explosion of inflammable air with common and dephlogisticated airs, except those which relate to the cause of the acid found in the water, were made in the summer of the year 1781, and were mentioned by me to Dr. Priestley, who in conse-

Antoine [illegible]

on his ear [illegible]
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LAVOISIER

Engraving from an original picture by David.

quence of it made some experiments of the same kind, as he relates in a paper printed in the preceding volume of the Transactions. During the last summer also, a friend of mine gave some account of them to M. Lavoisier, as well as of the conclusion drawn from them, that dephlogisticated air is only water deprived of phlogiston; but at that time so far was M. Lavoisier from thinking any such opinion warranted, that, till he was prevailed upon to repeat the experiment himself, he found some difficulty in believing that nearly the whole of the two airs could be converted into water. It is remarkable, that neither of these gentlemen found any acid in the water produced by the combustion; which might proceed from the latter having burnt the two airs in a different manner from what I did; and from the former having used a different kind of inflammable air, namely, that from charcoal, and perhaps having used a greater proportion of it.

LAVOISIER

Antoine Laurent Lavoisier was born in Paris, August 26, 1743. All his early life was devoted to the most arduous study. In 1766 he was voted the gold prize for his essay on the best way of lighting Paris. He had lived in a dark room for six weeks in making his experiments on the subject.

About 1770 his attention was called to the English experiments on gases—the so-called "new airs." He attacked the prevailing phlogiston theory of combustion and gave to Priestley's "dephlogisticated air" the virtue of being the universal acidifying gas, calling it oxygen. He declared combustion to be the act of some part of the substance combining with oxygen. He systematized chemistry and renamed the elements and their compounds. Chemical reaction came to him to have the certainty of an algebraic equation, and from this was developed the great idea of the persistence of matter, no difference what are the changes. This is one of the greatest principles of modern science.

Lavoisier was a prominent farmer of the taxes (publican) in France, and lent his aid to many improvements in public administration. During the mad times of the Revolution a charge was made against all farmers-general, and in spite of his greatness Lavoisier was sent to the guillotine May 6, 1794.

THE PERMANENCE OF MATTER

It results from the experiments described in chapters V and VI of the work which I published at the beginning of this year, under the title *Opuscules Physiques et Chimiques,* that when lead or tin is calcined in a retort (*verre ardent*) under a bell-glass plunged in water or in mercury, the volume of air is diminished about one-twentieth as a result of the calcination, while the weight of the metal is found to be increased by an amount approximately equal to that of the air destroyed or absorbed.

I felt justified in concluding from these experiments that a portion of the air itself, or of some substance contained in the air, and which exists there in an elastic state, combined with the metals during their calcination, and that the augmentation in weight of the metallic calxes was due to this cause.

The effervescence which constantly takes place in every revivification of metallic calxes, that is to say whenever a metallic substance passes from the condition of the calx (oxide) to that of the metal, came to the support of this theory. I think I have proved that this effervescence is due to the freeing of an elastic fluid, a kind of air (gas) which can be retained and measured, and the result of the many experiments to which I have subjected it is that when it had been separated from the metals by the addition of powdered charcoal, or any substance containing phlogiston, it did not differ in any respect from the substance to which I have given the name of fixed air, mephitic gas, mephitic acid, all synonymous terms, and that this gas was precisely the same whether disengaged from metallic calxes by means of powdered charcoal, from vegetable substances by fermentation, or from alkalies, saline or earthy, by their solution in acids.—Lavoisier on the Calcination of Tin, Oeuvres II., 105.

We began (our experiment) by testing what should be the opening of the stop-cocks to provide the due proportion of the two gases. This was easily ascertained by observing the color and brilliancy of the little tongues of flame which formed at the end of the tube, the right proportion of the two gases giving the most luminous and beautiful flame. This first point determined, we inserted the tube into the stem of the receiver, which was plunged into mercury, and allowed the gases to burn till we had used up all we had provided. From the first instant we saw the walls of the receiver becoming obscured and covered with vapor; soon this collected into drops and ran down upon the mercury from all sides, and in fifteen or twenty minutes its surface was completely covered. The difficulty was to collect this water, but that was easily accomplished by passing a plate under the receiver without taking that out of the mercury, and then pouring both the water and mercury into a glass funnel; finally letting the mercury run off, the water remained collected in the tube of the funnel; it weighed a little less than five drams (gross).

This water, subjected to every imaginable test, seemed as pure as distilled water; it did not redden at all the tincture of turnsol; nor turn green the syrup of violets; it did not precipitate lime-water; finally, one could not by any known reagents discover in it the slightest trace of admixture.

As the two airs [gases] were conducted from pneumatic receptacles (caisses) to the receiver through flexible leather pipes, and these were not absolutely impermeable to the air (gas) it was not possible for us to be certain as to the exact quantity of the two gases whose combustion we had thus brought about; but as it is not less true in physics than in geometry that the whole is equal to its parts, and as we had obtained by this experiment only pure water, without any other residue, we thought ourselves justified in concluding that the weight of this water was equal to that of the two gases which had served to produce it. But one reasonable objection could be brought against this conclusion: admitting that the water produced was equal in weight to the two gases, was to suppose that the matter of the heat and light so abundantly set free in this operation, and which passes through the pores of the vessels, had no weight; which assumption might be regarded as gratuitous. I found myself, therefore, confronted with this important question: whether the matter of heat and light has any sensible and appreciable weight in physical experiments, and I decided in the negative on the strength of facts which seemed to me conclusive and which I have set forth in a memoir deposited some months ago with the secretary of the Academy.—Lavoisier on the Composition of Water, Oeuvres II., 338, 339.

THE NATURE OF COMBUSTION

Emboldened by these reflections, I venture to submit to the Academy today a new theory of combustion, or rather, to speak with that reserve to whose law I submit myself, an hypothesis, by the aid of which all the phenomena of combustion, calcination, and even to some extent those accompanying the respiration of animals are explained in a very satisfactory manner. I had already laid the foundations of this hypothesis p. 279-280 of vol. I. of my *Opuscules physiques et chimiques;* but I admit that trusting little to my own knowledge, I did not then dare to put forward an opinion which might seem singular, and which was directly opposed to the theory of Stahl and of many celebrated men who have followed him.

Though perhaps some of the reasons which then checked me still remain today, nevertheless, the facts which have multiplied since that time, and which seem to me favorable to my views, have confirmed me in my opinion: though not, perhaps, any stronger, I have become more confident, and I think I have sufficient proofs, or at least probabilities, so that even those who may not be of my opinion cannot blame me for having written.

In general in the combustion of bodies four constant phenomena are observable, which seem to be laws from which nature never departs. Though these phenomena may be found implicitly stated in other memoirs, yet I cannot dispense with recalling them here in a few words.

First Phenomenon.

All combustion sets free matter either of fire or light.

Second Phenomenon.

Bodies can burn only in a very small number of kinds of gases (airs), or rather there can be combustion only in one kind of air, that which Mr. Priestley has named dephlogisticated air, and which I should call pure air. Not only will the bodies which we call combustibles not burn in a vacuum or in any other kind of air, they are, on the contrary, extinguished there as promptly as if they had been plunged into water or any other liquid.

Third Phenomenon.

In all combustion there is destruction or decomposition of the pure air in which the combustion takes place, and the body burned increases in weight exactly in proportion to the quantity of air destroyed or decomposed.

Fourth Phenomenon.

In all combustion the body burned changes to an acid by the addition of the substance which has increased its weight: thus, for example, if sulphur is burned under a receiver the product of the combustion is vitriolic acid; if phosphorus be burned the product is phosphoric acid; if a carboniferous substance, the product is fixed air, otherwise known as acid of lime (carbonic acid, etc.).

(Note: I would remark in passing that the number of acids is infinitely greater than has been supposed.)

The calcination of metals is subject to exactly the same laws, and it is with very great reason that Mr. Macquer has treated it as a slow combustion; thus, 1°, in all metallic combustion there is a liberating of fire matter (*matiere du feu*); 2°, veritable calcination can take place only in pure air; 3°, there is a combination of the air with the substance calcined, but with this difference, that in place of forming an acid with it there results from it a particular combination known as metallic calx.

This is not the place to point out the analogy which exists between the respiration of animals, combustion and calcination; I shall return to that in the sequel to this memoir.

These different phenomena of the calcination of metals and of combustion are explained in a very happy manner by Stahl's hypothesis; but it is necessary with him to suppose the existence of fire matter (*matiere du feu*) or of fixed phlogiston in the metals, in sulphur and in all bodies which he regards as combustibles; yet if the partisans of Stahl's doctrine are asked to prove the existence of fire matter in combustible bodies, they fall necessarily into a vicious circle and are obliged to reply that combustible bodies contain fire matter because they burn, and that they burn because they contain fire matter. It is easy to see that in the last analysis this is explaining combustion by combustion.

The existence of fire matter, or phlogiston, in metals, in sulphur, etc., is then really only an hypothesis, a supposition, which, once admitted, explains, it is true, some of the phenomena of calcination and combustion; but if I show that these very phenomena may be explained in quite as natural a way by the opposite hypothesis, that is to say, without supposing the existence of either fire matter or phlogiston in the substances called combustible, Stahl's system will be shaken to its foundations.

No doubt you will not fail to ask me first what I understand by fire matter. I reply with Franklin, Boerhaave and some of the philosophers of old, that the matter of fire or of light is a very subtle, very elastic fluid, which surrounds every part of the planet we live on, which penetrates with more or less ease the substances which compose that, and which tends, when it is free, to come to a state of equilibrium in all.

I will add, borrowing the chemical phraseology, that this fluid is the solvent of a large number of substances; that it combines with them in the same way that water does with salt, and the acids with metals, and that the bodies thus combined and dissolved by the igneous fluid lose in part the properties which they had before the combination and acquire new ones which bring them nearer (make them more like) the fire matter.

It is thus, as I have shown in a memoir deposited with the secretary of this Academy, that every aeriform fluid, every kind of air, is a resultant of the combination of some substance, solid or fluid, with the matter of fire or of light; and it is to this combination that aeriform fluids owe their elasticity, their specific volatility, their rarity, and all the other properties which ally (*rapprochent*) them to the igneous fluid.

Pure air, according to this, what Mr. Priestley calls dephlogisticated air, is an igneous compound into which the matter of fire or of light enters as solvent, and into which some other substance enters as a base; but if, in any solution whatever, a substance is presented to the base with which that has greater affinity, it unites with this instantly and the solvent which it leaves is set free.

The same thing happens with the air in combustion; the substance which burns steals away the base; then the fire matter which served as its solvent becomes free, regains its rights and escapes with the characteristics by which we know it; that is to say, with flame, heat and light.

To elucidate whatever may seem obscure in this theory let us apply it to some examples: when a metal is calcined in pure air, the base of the air, which has less affinity for its own solvent than for the metal, unites with the latter as it melts and converts it into metallic calx. This combination of the base of the air with the metal is proved 1st, by the increase in weight which the latter undergoes in calcination; 2nd, by the almost total using up of the air under the receiving bell. But, if the base of the air was held in solution by the fire-matter, in proportion as this base combined with the metal, the fire-matter should become free and produce, in freeing itself, flame and light. You understand that the more speedy the calcination of the metal, that is to say, the more fixation of the air takes place in a given time, the more fire-matter will be liberated, and, consequently, the more marked and obvious the combustion will be.

* * * *

I might apply this theory successively to all combustions, but as I shall have frequent occasion to return to this subject, I will content myself at this time with these general illustrations. So, to resume, the air is composed, according to my idea, of fire-matter as a dissolvent combined with a substance which serves it as a base, and which in some way neutralizes it; whenever a substance for which it has a greater affinity it brought into contact with this base, it leaves its solvent; then the fire-substance regains its rights, its properties, and appears to our eyes with heat, flame and light.

Pure air, the dephlogisticated air of Mr. Priestley, is then, according to this opinion, the real combustible body, and perhaps the only one of that nature, and it is seen that it is no longer necessary, in order to explain the phenomena of combustion, to suppose that there exists a large quantity of fire fixed in all the substances which we call combustible, but that it is very probable, on the contrary, that very little of it exists in metals, in sulphur, phosphorus, and in most of the very solid, heavy and compact bodies, and, perhaps, even that there exists in these substances only free fire-matter, in virtue of the property which this matter has of putting itself in equilibrium with all surrounding bodies.

Another striking reflection which comes to the support of the preceding ones, is that almost all substances may exist in three different states: under a solid form, under a liquid form, that is to say melted, or in the state of air or vapor. These three states depend solely on the quantity, more or less, of fire-matter with which these substances are interpenetrated and with which they are combined. Fluidity, vaporization, elasticity, are then properties characteristic of the presence of fire and of a great abundance of fire; solidity, compactness, on the contrary, are evidences of its absence. By so much then as it is demonstrated that aeriform substances and air itself contain a large quantity of fire in combination, by so much it is probable that solid bodies contain little of it.

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For the rest, I repeat, in attacking here the doctrine of Stahl; it was not my purpose to substitute for it a rigorously demonstrated theory, but only an hypothesis which seemed to me more probable, more in conformity with the laws of nature, and one which appeared to involve less forced explanations and fewer contradictions.—On Combustion, II. 225.

RESPIRATION A COMBUSTION

Respiration is a combustion, very slow, indeed, but otherwise precisely similar to that of carbon; it takes place in the lungs, without producing sensible light, because the fire-matter set free is at once absorbed by the humidity of these organs; the heat developed in this combustion is communicated to the blood which traverses the lungs, and from there is diffused throughout the entire animal system. Hence the air we breathe serves two purposes equally necessary for our conservation; it removes from the blood the base of fixed air whose overabundance would be very injurious; and the heat which this combination produces in the lungs repairs the constant loss of heat which we experience through the atmosphere and surrounding objects.

Animal heat is about the same in different parts of the body; this effect seems to depend on the three following causes: first, the rapidity of the circulation of the blood, which promptly transmits even to the extremities of the body the heat which it receives in the lungs; the second cause is the evaporation which the heat produces in these organs, and which diminishes the degree of their temperature; finally, the third is connected with the increase observed in the specific heat of the blood, when, by contact with pure air, it rids itself of the base of fixed air which it contains; a part of the specific heat developed in the formation of fixed air [carbonic acid gas] is thus absorbed by the blood, its temperature remaining always the same; but when, in the circulation, the blood takes up again the base of fixed air, its specific heat diminishes, and heat is developed; and, as this combination takes place in all parts of the body, the heat which it produces contributes to maintaining the temperature of parts distant from the lungs at about the same degree as that of these organs. Furthermore, whatever may be the manner in which the animal heat is kept up, that which is produced by the formation of fixed air is its first cause; hence we may establish the following proposition: *When an animal is in a permanent and tranquil state; when it can live for a considerable time, without suffering, in the environment which surrounds it; in general, when the circumstances in which it finds itself do not sensibly impair its blood or its humors, so that after several hours the animal system experiences no sensible variation; the con-*

servation of the animal heat is due, at least in large part, to the heat which the combination of the pure air respired by the animal with the base of fixed air which the blood supplies to it, produces.

JAMES WATT

James Watt was born at Greenock, Scotland, January 19, 1736. In childhood he showed signs of an inventive ability and when a young man learned to make mathematical instruments as a trade. In 1757 he became instrument maker to the University of Glasgow. Not long afterwards he was given a model of a Newcomen steam engine to repair and was led to note its defects and eventually to his great invention.

In Newcomen's engine, which was used for pumping water from mines, the steam was let into the bottom of a vertical cylinder. This allowed the piston to be pulled up by a counterpoise at the farther end of a beam. Then the boiler was disconnected, the steam in the cylinder condensed by cold water, and the air forced the piston down, which latter action did the work of the engine. Watt was a friend of Joseph Black, and learned from him that the fact that heat becomes latent in changing water into steam, would cause a great loss of energy in alternately cooling the cylinder in condensing the steam and in having to heat it before the steam would force the piston to rise. Watt's process of thought in overcoming the difficulty is given below. In brief, the result was the condensation of the steam in a separate vessel.

The new engine was patented in 1769. In the meantime Watt had become a surveyor and continued to make his living in this way until the manufacture of his engines was at length put on a paying basis under the firm of Boulton and Watt. His death was in 1819.

INVENTION OF THE STEAM ENGINE

My attention was first directed, in the year 1759, to the subject of steam-engines, by the late Dr. Robison, then a student in the University of Glasgow, and nearly of my own age. He at that time threw out an idea of applying the power of the steam-engine to the moving of wheel-carriages, and to other purposes, but the scheme was not matured, and was soon abandoned on his going abroad.

About the year 1761 or 1762 I tried some experiments on the force of steam in a Papin's digester, and formed a species of steam-engine by fixing upon it a syringe, one-third of an inch diameter, with a solid piston, and furnished also with a cock to admit the steam from the digester, or shut it off at pleasure, as well as to open a communication from the inside of the syringe to the open air, by which the steam contained in the syringe might escape. When the communication between the digester and syringe was opened, the steam entered the syringe, and by its action upon the piston raised a considerable weight (15 lbs.) with which it was loaded. When this was raised as high as was thought proper, the communication with the digester was shut, and that with the atmosphere opened; the steam then made its escape, and the weight descended. The operations were repeated, and, though in this experiment the cock was turned by hand, it was easy to see how it could be done by the machine itself, and to make it work with perfect regularity. But I soon relinquished the idea of constructing an engine upon its principle, from being sensible it would be liable to some of the objections against Savery's engine, viz., the danger of bursting the boiler, and the difficulty of making the joints tight, and also that a great part of the power of the steam would be lost, because no vacuum was formed to assist the descent of the piston. I, however, described this engine in the fourth article of the specification of my patent of 1769; and again in the specification of another patent in the year 1784, together with a mode of applying it to the moving of wheel-carriages.

The attention necessary to the avocations of business prevented me from then prosecuting the subject further, but in the winter of 1763-4, having occasion to repair a model of Newcomen's engine belonging to the Natural Philosophy class of the University of Glasgow, my mind was again directed to it. At that period my knowledge was derived principally from Desaguliers, and partly from Belidor. I set about repairing it as a mere mechanician; and when that was done, and it was set to work, I was surprised to find that its boiler could not supply it with steam, though apparently quite large enough, (the cylinder of the model being two inches in diameter, and six inches stroke, and the boiler about nine inches diameter). By blowing the fire it was made to take a few strokes, but required an enormous quantity of injection water, though it was very lightly loaded by the column of water in the pump. It soon occurred that this was caused by the little cylinder exposing a greater surface to condense the steam, than the cylinders of larger engines did in proportion to their respective contents. It was found that by shortening the column of water in the pump, the boiler could supply the cylinder with steam, and that the engine would work regularly with a moderate quantity of injection. It now appeared that the cylinder of the model, being of brass, would conduct heat much better than the cast-iron cylinders of larger engines, (generally covered on the inside with a stony crust,) and that considerable advantage could be gained by making the cylinders of some substance that would receive and give out heat slowly. Of these wood seemed to be the most likely, provided it should prove sufficiently durable. A small engine was, therefore, constructed, with a cylinder six inches diameter, and twelve inches stroke, made of wood, soaked in linseed oil, and baked to dryness. With this engine many experiments were made, but it was soon found that the wooden cylinder was not likely to prove durable, and that the steam condensed in filling it still exceeded the proportion of that required for large engines, according to the statements of Desaguliers. It was also found that all attempts to produce a better exhaustion by throwing in more injection, caused a disproportionate waste of steam. On reflection, the cause of this seemed to be the boiling of water in vacuo at low heats, a discovery lately made by Dr. Cullen and some other philosophers, (below 100°, as I was then informed,) and consequently, at greater heats, the water in the cylinder would produce a steam which would, in part, resist the pressure of the atmosphere.

By experiments which I then tried upon the heats at which water boils under several pressures greater than that of the atmosphere, it appeared that when the heats proceeded in an arithmetical, the elasticities proceeded in some geometrical ratio; and, by laying down a curve from my data, I ascertained the particular one near enough for my purpose. It also appeared that any approach to a vacuum could only be obtained by throwing in large quantities of injection, which would cool the cylinder so much as to require quantities of steam to heat it again, out of proportion to the power gained by the more perfect vacuum, and that the old engineers had acted wisely in contenting themselves with loading the engine with only six or seven pounds on each square inch of the area of the piston. It being evident that there was a great error in Dr. Desaguliers' calculations of Mr. Beighton's experiments on the bulk of setam, a Florence flask, capable of containing about a pound of water, had about one ounce of distilled water put into it; a glass tube was fitted into its mouth, and the joining made tight by lapping that part of the tube with pack-thread, covered with glazier's putty. When the flask was set upright, the tube reached down near to the surface of the water, and in that position the whole was placed in a tin reflecting oven before a fire, until the water was wholly evaporated, which happened in about an hour, and might have been done sooner had I not wished the heat not much to exceed that of boiling water. As the air in the flask was heavier than the steam, the latter ascended to the top, and expelled the air through the tube. When the water was all evaporated, the oven and flask were removed from the fire, and a blast of cold air was directed against one side of the flask, to collect the condensed steam in one place. When all was cold, the tube was removed, the flask and its contents were weighed with care, and the flask being made hot, it was dried by blowing into it by bellows, and, when weighed again, was found to have lost rather more than 4 grains, estimated at 4 1-3 grains. When the flask was filled with water, it was found to contain about 17⅛ ounces avoirdupois of that fluid, which gave about 1800 for the expansion of water converted into steam of the heat of boiling water.

This experiment was repeated with nearly the same result, and in order to ascertain whether the flask had been wholly filled with steam, a similar quantity of water was for the third time evaporated, and, while the flask was still cold, it was placed inverted, with its mouth (contracted by the tube) immersed in a vessel of water, which it sucked in as it cooled, until in the temperature of the atmosphere it was filled to within half an ounce measure of water. In the contrivance of this experiment I was assisted by Dr. Black. In Dr. Robison's edition of Dr. Black's lectures, vol. i., p. 147, the latter hints at some experiments upon this subject, as made by him, but I have no knowledge of any except those which I made myself.

In repetitions of this experiment at a later date, I simplified the apparatus by omitting the tube and laying the flask upon its side in the oven, partly closing its mouth by a cork, having a notch on one side, and otherwise proceeding as has been mentioned.

I do not consider these experiments as extremely accurate, the only scale-beam of a proper size which I had then at my command not being very sensible, and the bulk of the steam being liable to be influenced by the heat to which it is exposed, which, in the way described, is not easily regulated or ascertained; but, from my experience in actual practice, I esteem the expansion to be rather more than I have computed.

A boiler was constructed which showed, by inspection, the quantity of water evaporated in any given time, and thereby ascertained the quantity of steam used in every stroke by the engine, which I found to be several times the full of the cylinder. Astonished at the quantity of water required for the injection, and the great heat it had acquired from the small quantity of water in the form of steam which had been used in filling the cylinder, and thinking I had made some mistake, the following experiment was tried:—A glass tube was bent at right angles; one end was inserted horizontally into the spout of a tea-kettle, and the other part was immersed perpendicularly in well-water contained in a cylindric glass vessel, and steam was made to pass through it until it ceased to be condensed, and the water in the glass vessel was become nearly boiling hot. The water in the glass vessel was then found to have gained an addition of about one-sixth part from the condensed steam. Consequently, water converted into steam can heat about six times its own weight of well-water to 212°, or till it can condense no more steam. Being struck with this remarkable fact, and not understanding the reason of it, I mentioned it to my friend Dr. Black, who then explained to me his doctrine of latent heat, which he had taught for some time before this period, (summer 1764,) but having myself been occupied with the pursuits of business, if I had heard of it, I had not attended to it, when I thus stumbled upon one of the material facts by which that beautiful theory is supported.

On reflecting further I perceived that, in order to make the best use of steam, it was necessary—first, that the cylinder should be maintained always as hot as the steam which entered it; and, secondly, that when the steam was condensed, the water of which it was composed, and the injection itself, should be cooled down to 100°, or lower, where that was possible. The means of accomplishing these points did not immediately present themselves, but early in 1765 it occurred to me, that if a communication were opened between a cylinder containing steam and another vessel which was exhausted of air and other fluids, the steam, as an elastic fluid, would immediately rush into the empty vessel, and continue so to do until it had established an equilibrium, and if that vessel were kept very cool by an injection, or otherwise, more steam would continue to enter until the whole was condensed. But both the vessels being exhausted, or nearly so, how were the injection-water, the air which would enter with it, and the condensed steam, to be got out? This I proposed, in my own mind, to perform in two ways. One was, by adapting to the second vessel a pipe, reaching downwards more than 34 feet, by which the water would descend, (a column of that length overbalancing the atmosphere,) and by extracting the air by means of a pump.

The second method was by employing a pump, or pumps, to extract both the air and the water, which would be applicable in all places, and essential in those cases where there was no well or pit.

This latter method was the one I then preferred, and is the only one I afterwards continued to use.

In Newcomen's engine the piston is kept tight by water, which could not be applicable in this new method; as, if any of it entered into a partially exhausted and hot cylinder, it would boil, and prevent the production of a vacuum, and would also cool the cylinder by its evaporation during the descent of the piston. I proposed to remedy this defect by employing wax, tallow, or other grease, to lubricate and keep the piston tight. It next occurred to me that, the mouth of the cylinder being open, the air which opened to act on the piston would cool the cylinder, and condense some steam on again filling it. I therefore proposed to put an air-tight cover upon the cylinder, with a hole and stuffing-box for the piston to slide through, and to admit steam above the piston to act upon it, instead of the atmosphere. The piston-rod sliding through a stuffing-box was new in steam-engines; it was not necessary in Newcomen's engine, as the mouth of the cylinder was open, and the piston-rod was square and very clumsy. The fitting the piston-rod to the piston by a cone was an after improvement of mine, (about 1774). There still remained another source of the destruction of steam, the cooling of the cylinder by the external air, which would produce an internal condensation whenever steam entered it, and which would be repeated every stroke; this I proposed to remedy by an external cylinder, containing steam, surrounded by another of wood, or of some other substance which would conduct heat slowly.

When once the idea of the separate condensation was started, all these improvements followed as corollaries in quick succession, so that in the course of one or two days the invention was thus far complete in my mind, and I immediately set about an experiment to verify it practically. I took a large brass syringe, 1¾ inches diameter and 10 inches long, made a cover and bottom to it of tin-plate, with a pipe to convey steam to both ends of the cylinder from the boiler; another pipe to convey steam from the upper end to the condenser, (for, to save apparatus, I inverted the cylinder;) I drilled a hole longitudinally through the axis of the stem of the piston, and fixed a valve at its lower end, to permit the water, which was produced by the condensed steam on first filling the cylinder, to issue. The condenser used upon this occasion consisted of two pipes of thin tin-plate, ten or twelve inches long, and about one-sixth inch diameter, standing perpendicular, and communicating at top with a short horizontal pipe of large diameter, having an aperture on its upper side, which was shut by a valve opening upwards. These pipes were joined at bottom to another perpendicular pipe of about an inch diameter, which served for the air and water-pump, and both the condensing pipes and the air-pump were placed in a small cistern filled with cold water. This construction of the condenser was employed from knowing that heat penetrated thin plates of metal very quickly, and considering that if no injection was thrown into an exhausted vessel, there would be only the water of which the steam had been composed, and the air which entered with the steam, or through the leaks, to extract.

The steam-pipe was adjusted to a small boiler. When steam was produced, it was admitted into the cylinder, and soon issued through the perforation of the rod, and at the valve of the condenser. When it was judged that the air was expelled, the steam-cock was shut, and the air-pump piston-rod was drawn up, which leaving the small pipes of the condenser in a state of vacuum, the steam entered them and was condensed. The piston of the cylinder immediately rose, and lifted a weight of about 18 lbs., which was hung to the lower end of the piston-rod. The exhaustion-cock was shut, the steam was readmitted into the cylinder, and the operation was repeated; the quantity of steam consumed, and the weights it could raise, were observed, and, excepting the non-application of the steam-case and external covering, the invention was complete, in so far as regarded the savings of steam and fuel. A large model, with an outer cylinder and wooden case, was immediately constructed, and the experiments made with it served to verify the expectations I had formed, and to place the advantage of the invention beyond the reach of doubt. It was found convenient afterwards to change the pipe-condenser for an empty vessel, generally of a cylindrical form, into which an injection played, and, in consequence of there being more water and air to extract, to enlarge the air-pump.

The change was made because, in order to procure a surface sufficiently extensive to condense the steam of a large engine, the pipe-condenser would require to be very voluminous, and because the bad water with which engines are frequently supplied would crust over the thin plates, and prevent their conveying the heat sufficiently quick. The cylinders were also placed with their mouths upwards, and furnished with a working-beam and other apparatus, as was usual in the ancient engines; the inversion of the cylinder, or rather of the piston-rod, in the model, being only an expedient to try more easily the new invention, and being subject to many objections in large engines.

In 1768 I applied for letters patent for my "Methods of Lessening the Consumption of Steam, and, consequently, of Fuel, in Fire-Engines," which passed the seals in January, 1769; and my Specification was enrolled in Chancery in April following.

HUTTON

James Hutton was born in Edinburgh in 1726. He studied in that city, then traveled in Europe and finally took his medical degree in 1749. In the same year he returned to England to practice, but gave it up the next year for agriculture. At this time he became interested in the structure of the earth.

Anyone that has read Ovid will remember the old Pythagorean view of geology.

In 1519 Leonardo da Vinci and in 1580 Palissy in Paris wrote against the prevalent idea that the earth had always remained as it was, and that fossils were stones ready made by nature, but the old idea held its own until the last century. Leibnitz in 1680 propounded the theory that the earth was once a luminous burning mass. But geology was held back by the fear of conflicting with the Mosaic doctrine of the earth's creation. In the last quarter of the eighteenth century Werner, Professor of Mineralogy at Freiburg, Germany, developed his doctrine of the formation of the strata by precipitation from the ocean. He believed that such rocks as granite (the chemical rocks) were first made and are the bases of all others.

Hutton found evidences of volcanic origin and the production of rock from a fused state. He taught that materials laid down and compressed by the sea were upheaved by central heat, and that they were subsequently gradually worn away by the action of the weather. His doctrine "In the economy of the world, I can find no traces of a beginning, no prospect of an end," brought him into disrepute with theology. A violent quarrel arose between the Neptunists (followers of Werner) and the Vulcanists (followers of Hutton), that raged until the time of Lyell.

Hutton died in 1797. With his rival, Werner, he opened up the way in geology. His system owed its extension and popularity largely to the brilliant account of it by his friend John Playfair, Professor of Mathematics in Edinburgh.

HUTTON'S THEORY OF THE PHENOMENA COMMON TO STRATIFIED AND UNSTRATIFIED BODIES

The series of changes which fossil bodies are destined to undergo, does not cease with their elevation above the level of the sea; it assumes, however, a new direction, and from the moment that they are raised up to the surface, is constantly exerted in reducing them again under the dominion of the ocean. The solidity is now destroyed which was acquired in the bowels of the earth; and as the bottom of the sea is the great laboratory, where loose materials are mineralized and formed into stone, the atmosphere is the region where stones are decomposed, and again resolved into earth.

This decomposition of all mineral substances, exposed to the air, is continual, and is brought about by a multitude of agents, both chemical and mechanical, of which some are known to us, and many, no doubt, remain to be discovered. Among the various aëriform fluids which compose our atmosphere, one is already distinguished as the grand principle of mineral decomposition; the others are not inactive, and to them we must add moisture, heat, and perhaps light; substances which, from their affinities to the elements of mineral bodies, have a power of entering into combination with them, and of thus diminishing the forces by which they are united to one another. By the action of air and moisture, the metallic particles, particularly the iron, which enters in great abundance into the composition of almost all fossils, becomes oxydated in such a degree as to lose its tenacity; so that the texture of the surface is destroyed, and a part of the body resolved into earth.

Some earths, again, such as the calcareous, are immediately dissolved by water; and though the quantity so dissolved be extremely small, the operation, by being continually renewed, produces a slow but perpetual corrosion, by which the greatest rocks must in time be subdued. The action of water in destroying hard bodies into which it has obtained entrance, is much assisted by the vicissitudes of heat and cold, especially when the latter extends as far as the point of congelation; for the water when frozen, occupies a greater space than before, and if the body is compact enough to refuse room for this expansion, its parts are torn asunder by a repulsive force acting in every direction.

Beside these causes of mineral decomposition, the action of which we can in some measure trace, there are others known to us only by their effects.

We see, for instance, the purest rock crystal affected by exposure to the weather, its lustre tarnished, and the polish of its surface impaired, but we know nothing of the power by which these operations are performed. Thus also, in the precautions which the mineralogist takes to preserve the fresh fracture of his specimens, we have a proof how indiscriminately all the productions of the animal kingdom are exposed to the attacks of their unknown enemies, and we perceive how difficult it is to delay the beginnings of a process which no power whatever can finally counteract.

The mechanical forces employed in the disintegration of mineral substances, are more easily marked than the chemical. Here again water appears as the most active enemy of hard and solid bodies; and, in every state, from transparent vapour to solid ice, from the smallest rill to the greatest river, it attacks whatever has emerged above the level of the sea, and labours incessantly to restore it to the deep. The parts loosened and disengaged by the chemical agents, are carried down by the rains, and, in their descent, rub and grind the superficies of other bodies. Thus water, though incapable of acting on hard substances by direct attrition, is the cause of their being so acted on; and, when it descends in torrents, carrying with it sand, gravel, and fragments of rock, it may be truly said to turn the forces of the mineral kingdom against itself. Every separation which it makes is necessarily permanent, and the parts once detached can never be united, save at the bottom of the ocean.

But it would far exceed the limits of this sketch, to pursue the causes of mineral decomposition through all their forms. It is sufficient to remark, that the consequence of so many minute, but indefatigable agents, all working together, and having gravity in their favour, is a system of universal decay and degradation, which may be traced over the whole surface of the land, from the mountain top to the sea shore. That we may perceive the full evidence of this truth, one of the most important in the natural history of the globe, we will begin our survey from the latter of these stations, and retire gradually toward the former.

If the coast is bold and rocky, it speaks a language easy to be interpreted. Its broken and abrupt contour, the deep gulfs and salient promontories by which it is indented, and the proportion which these irregularities bear to the force of the waves, combined with the inequality of hardness in the rocks, prove, that the present line of shore has been determined by the action of the sea. The naked and precipitous cliffs which overhang the deep, the rocks hollowed, perforated, as they are farther advanced in the sea, and at last insulated, lead to the same conclusion, and mark very clearly so many different stages of decay. It is true, we do not see the successive steps of this progress exemplified in the states of the same individual rock, but we see them clearly in different individuals; and the conviction thus produced, when the phenomena are sufficiently multiplied and varied, is as irresistible, as if we saw the changes actually effected in the moment of observation.

On such shores, the fragments of rock once detached, become instruments of further destruction, and make a part of the powerful artillery with which the ocean assails the bulwarks of the land: they are impelled against the rocks, from which they break off other fragments, and the whole are thus ground against one another; whatever be their hardness, they are reduced to gravel, the smooth surface and round figure of which, are the most certain proofs of a detritus which nothing can resist.

Again, where the sea coast is flat, we have abundant evidence of the degradation of the land in the beaches of sand and small gravel; the sand banks and shoals that are constantly changing; the alluvial land at the mouths of the rivers; the bars that seem to oppose their discharge into the sea, and the shallowness of the sea itself. On such coasts, the land usually seems to gain upon the sea, whereas, on shores of a bolder aspect, it is the sea that generally appears to gain upon the land. What the land acquires in extent, however, it loses in elevation; and, whether its surface increase or diminish, the depredations made on it are in both cases evinced with equal certainty.

If we proceed in our survey from the shores, inland, we meet at every step with the fullest evidence of the same truths, and particularly in the nature and economy of rivers. Every river seems to consist of a main trunk, fed from a variety of branches, each running in a valley proportioned to its size, and all of them together forming a system of valleys, communicating with one another, and having such a nice adjustment of their declivities, that none of them join the principal valley, either on too high or too low a level; a circumstance which would be infinitely improbable, if each of these valleys were not the work of the stream that flows in it.

If indeed a river consisted of a single stream, without branches, running in a straight valley, it might be supposed that some great concussion, or some powerful torrent, had opened at once the channel by which its waters are conducted to the ocean; but, when the usual form of a river is considered, the trunk divided into many branches, which rise at a great distance from one another, and these again subdivided into an infinity of smaller ramifications, it becomes strongly impressed upon the mind, that all these channels have been cut by the waters themselves; that they have been slowly dug out by the washing and erosion of the land; and that it is by the repeated touches of the same instrument, that this curious assemblage of lines has been engraved so deeply on the surface of the globe.

The changes which have taken place in the courses of rivers, are also to be traced, in many instances, by successive platforms, of flat alluvial land, rising one above another, and marking the different levels on which the river has run at different periods of time. Of these, the number to be distinguished, in some instances, is not less than four, or even five; and this necessarily carries us back, like all the operations we are now treating of, to an antiquity extremely remote: for, if it be considered, that each change which the river makes in its bed, obliterates at least a part of the monuments of former changes, we shall be convinced, that only a small part of the progression can leave any distinct memorial behind it, and that there is no reason to think, that, in the part which we see, the beginning is included.

In the same manner, when a river undermines its banks, it often discovers deposits of sand and gravel, that have been made when it ran on a higher level than it does at present. In other instances, the same strata are seen on both the banks, though the bed of the river is now sunk deep between them, and perhaps holds as winding a course through the solid rock, as if it flowed along the surface; a proof that it must have begun to sink its bed, when it ran through such loose materials as opposed but a very inconsiderable resistance to its stream. A river, of which the course is both serpentine and deeply excavated in the rock, is among the phenomena, by which the slow waste of the land, and also the cause of that waste, are most directly pointed out.

It is, however, where rivers issue through narrow defiles among mountains, that the identity of the strata on both sides is most easily recognized, and remarked at the same time with the greatest wonder. On observing the Potomack, where it penetrates the ridge of the Alegany mountains, or the Irtish, as it issues from the defiles of Altai, there is no man, however little addicted to geological speculations, who does not immediately acknowledge that the mountain was once continued quite across the space in which the river now flows; and if he ventures to reason concerning the cause of so wonderful a change, he ascribes it to some great convulsion of nature, which has torn the mountain asunder, and opened a passage for the waters. It is only the philosopher, who has deeply meditated on the effects which action long continued is able to produce, and on the simplicity of the means which nature employs in all her operations, who sees in this nothing but the gradual working of a stream, that once flowed over the top of the ridge which it now intersects, and has cut its course through the rock, in the same way, and almost with the same instrument, by which the lapidary divides a block of marble or granite.

It is highly interesting to trace up, in this manner, the action of causes with which we are familiar, to the production of effects, which at first seem to require the introduction of unknown and extraordinary powers; and it is no less interesting to observe, how skilfully nature has balanced the action of all the minute causes of waste, and rendered them conducive to the general good. Of this we have a most remarkable instance, in the provision made for preserving the soil, or the coat of vegetable mould spread out over the surface of the earth. This coat, as it consists of loose materials, is easily washed away by the rains, and is continually carried down by the rivers into the sea. This effect is visible to every one; the earth is removed not only in the form of sand and gravel, but its finer particles suspended in the waters, tinge those of some rivers continually, and those of all occasionally, that is, when they are flooded or swollen with rains. The quantity of earth thus carried down, varies according to circumstances; it has been computed, in some instances, that the water of a river in a flood, contains earthy matter suspended in it, amounting to more than the two hundred and fiftieth part of its own bulk. The soil, therefore, is continually diminished, its parts being transported from higher to lower levels, and finally delivered into the sea. But it is a fact, that the soil, notwithstanding, remains the same in quantity, or at least nearly the same, and must have done so, ever since the earth was the receptacle of animal or vegetable life. The soil, therefore, is augmented from other causes, just as much, at an average, as it is diminished by that now mentioned; and this augmentation evidently can proceed from nothing but the contanst and slow disintegration of the rocks. In the permanence, therefore, of a coat of vegetable mould on the surface of the earth, we have a demonstrative proof of the continual destruction of the rocks; and cannot but admire the skill with which the powers of the many chemical and mechanical agents employed in this complicated work, are so adjusted, as to make the supply and the waste of the soil exactly equal to one another.

Before we take leave of the rivers and the plains, we must remark another fact, often observed in the natural history of the latter, and clearly evincing the former existence of immense bodies of strata, in situations from which they have now entirely disappeared. The fact here alluded to is, the great quantity of round and hard gravel, often to be met with in the soil, under such circumstances, as prove, that it can only have come from the decomposition of rocks, that once occupied the very ground over which this gravel is now spread. In the chalk country, for instance, about London, the quantity of flints in the soil is every where great; and, in particular situations, nothing but flinty gravel is found to a considerable depth. Now, the source from which these flints are derived is quite evident, for they are precisely the same with those contained in the chalk beds, wherever these last are found undisturbed, and from the destruction of such beds they no doubt originated. Hence a great thickness of chalk must have been decomposed, to yield the quantities of flints now in the soil of these countries; for the flints are but thinly scattered through the native chalk, compared with their abundance in the loose earth. To afford, for example, such a body of flinty gravel as is found about Kensington, what an enormous quantity of chalk rock must have been destroyed?

This argument, which Dr. Hutton has applied particularly to the chalk countries, may be extended to many others. The great plain of Crau, near the mouth of the Rhone, is well known, and is regarded with wonder, even in ages when the natural history of the globe was not an object of much attention. The immense quantity of large round gravel stones, with which this extensive plain is entirely covered, has been supposed, by some mineralogists, to have been brought down by the Durance, and other torrents, from the Alps; but, on further examination, has been found to be of the same kind that is contained in certain horizontal layers of pudding-stone, which are the basis of the whole plain. It cannot be doubted, therefore, that the vast body of gravel spread over it, has originated from the destruction of layers of the same rock, which may perhaps have risen to a great height above what is now the surface. Indeed, from knowing the depth of the gravel that covers the plain, and the average quantity of the like gravel contained in a given thickness of rock, one might estimate how much of the latter has been actually worn away. Whether data precise enough could be found, to give any weight to such a computation, must be left for future inquiry to determine.

In these instances, chalk and pudding-stone, by containing in themselves parts infinitely less destructible than their general mass, have, after they are worn away, left behind them very unequivocal marks of their existence. The same has happened in the case of mineral veins, where the substances least subject to dissolution have remained, and are scattered at a great distance from their native place. Thus gold, the least liable to decomposition of all the metals, is very generally diffused through the earth, and is found, in a greater or less abundance, in the sand of almost all rivers. But the native place of this mineral is the solid rock, and from thence it must have made its way into the soil. This, therefore, is another proof of the vast extent to which the degradation of the land, and of the rock, which is the basis of it, has been carried; and consequently, of the great difference between the elevation and shape of the earth's surface in the present, and in former ages.

The veins of tin furnish an argument of the same kind. The ores of this metal are very indestructible, and little subject to decomposition, so that they remain very long in the ground without change. Where there are tin veins, as in Cornwall, the tin-stone or tin ore is found in great abundance in such vallies or streams as have the same direction with the veins; and hence the streaming, as it is called, or washing of the earth, to obtain the tin-stone from it. Now, if it be considered, that none of this ore can have come into the soil but from parts of a vein actually destroyed, it must appear evident that a great waste of these veins has taken place, and consequently of the schistus or granite in which they are contained.

These lessons, which the geologist is taught in flat and open countries, become more striking, by the study of those Alpine tracts, where the surface of the earth attains its greatest elevation. If we suppose him placed for the first time in the midst of such a scene, as soon as he has recovered from the impression made by the novelty and magnificence of the spectacle before him, he begins to discover the footsteps of time, and to perceive, that the works of nature, usually deemed the most permanent, are those on which the characters of vicissitude are most deeply imprinted. He sees himself in the midst of a vast ruin, where the precipices which rise on all sides with such boldness and asperity, the sharp peaks of the granite mountains, and the huge fragments that surround their bases, do but mark so many epochs in the progress of decay, and point out the energy of those destructive causes, which even the magnitude and solidity of such great bodies have been unable to resist.

The result of a more minute investigation, is in perfect unison with this general impression. Whence is it, that the elevation of mountains is so obviously connected with the hardness and indestructibility of the rocks which compose them? Why is it, that a lofty mountain of soft and secondary rock is nowhere to be found; and that such chains, as the Pyrenees or the Alps, never consist of any but the hardest stone, of granite, for instance, or of those primary strata, which, if we are to credit the preceding theory, have been twice heated in the fires, and twice tempered in the waters, of the mineral regions? Is it not plain that this arises, not from any direct connection between the hardness of stones, and their height in the atmosphere, but from this, that the waste and detritus to which all things are subject, will not allow soft and weak substances to remain long in an exposed and elevated situation? Were it not for this, the secondary rocks would be in position superincumbent on the primary, (as they no doubt have at one time been,) in the highest as well as the lowest situations, or among the mountains as well as the plains.

Again, wherefore is it, that among all mountains, remarkable for their ruggedness and asperity, the rock, on examination, is always found of very unequal destructibility, some parts yielding to the weather, and to the other causes of disintegration, much more slowly than the rest, and having strength sufficient to support themselves, when left alone, in slender pyramids, bold projections, and overhanging cliffs? Where, on the other hand, the rock wastes uniformly, the mountains are similar to one another; their swells and slopes are gentle, and they are bounded by a waving and continuous surface. The intermediate degrees of resistance which the rocks oppose to the causes of destruction, produce intermediate forms. It is this which gives to the mountains, of every different species of rock, a different habit and expression, and which, in particular, has imparted to those of granite that venerable and majestic character, by which they rarely fail to be distinguished.

The structure of the vallies among the mountains, shows clearly to what cause their existence is to be ascribed. Here we have first a large valley, communicating directly with the plain, and winding between high ridges of mountains, while the river in the bottom of it descends over a surface, remarkable, in such a scene, for its uniform declivity. Into this, open a multitude of transverse or secondary vallies, intersecting the ridges on either side of the former, each bringing a contribution to the main stream, proportioned to its magniture; and, except where a cataract now and then intervenes, all having that nice adjustment in their levels, which is the more wonderful, the greater the irregularity of the surface. These secondary vallies have others of a smaller size opening into them; and, among mountains of the first order, where all is laid out on the greatest scale, these ramifications are continued to a fourth, and even a fifth, each diminishing in size as it increases in elevation, and as its supply of water is less. Through them all this law is in general observed, that where a higher valley joins a lower one, of the two angles which it makes with the latter, that which is obtuse is always on the descending side; a law that is the same with that which regulates the confluence of streams running on a surface nearly of uniform inclination. This alone is a proof that the vallies are the work of the streams; and indeed what else but the water itself, working its way through obstacles of unequal resistance, could have opened or kept up a communication between the inequalities of an irregular and alpine surface?

Many more arguments, all leading to the same conclusion, may be deduced from the general facts, known in the natural history of mountains; and, if the Oreologist would trace back the progress of waste, till he come in sight of that original structure, of which the remains are still so vast, he perceives an immense mass of solid rock, naked and unshapely, as it first emerged from the deep, and incomparably greater than all that is now before him. The operation of rains and torrents, modified by the hardness and tenacity of the rock, has worked out the whole into its present form; has hollowed out the vallies, and gradually detached the mountains from the general mass, cutting down their sides into steep precipices at one place, and smoothing them into gentle declivities at another. From this has resulted a transportation of materials, which, both for the quantity of the whole, and the magnitude of the individual fragments, must seem incredible to every one, who has not learned to calculate the effects of continued action, and to reflect, that length of time can convert accidental into steady causes. Hence fragments of rock, from the central chain, are found to have travelled into distant vallies, even where many inferior ridges intervene: hence the granite of Mont Blanc is seen in the plains of Lombardy, or on the sides of Jura; and the ruins of the Carpathian mountains lie scattered over the shores of the Baltic.

Thus, with Dr. Hutton, we shall be disposed to consider those great chains of mountains, which traverse the surface of the globe, as cut out of masses vastly greater, and more lofty than any thing that now remains. The present appearances afford no data for calculating the original magnitude of these masses, or the height to which they may have been elevated. The nearest estimate we can form is, where a chain or group of mountains, like those of Bosa in the Alps, is horizontally stratified, and where, of consequence, the undisturbed position of the mineral beds enables us to refer the whole of the present inequalities of the surface to the operation of waste or decay. These mountains, as they now stand, may not inaptly be compared to the pillars of earth which workmen leave behind them, to afford a measure of the whole quantity of earth which they have removed. As the pillars, (considering the mountains as such,) are in this case of less height than they originally were, so the measure furnished by them is but a limit, which the quantity sought must necessarily exceed.

Such, according to Dr. Hutton's theory, are the changes which the daily operations of waste have produced on the surface of the globe. These operations, inconsiderable if taken separately, become great, by inspiring all to the same end, never counteracting one another, but proceeding, through a period of indefinite extent, continually in the same direction. Thus every thing descends, nothing returns upward; the hard and soft bodies every where dissolve, and the loose and soft no where consolidate. The powers which tend to preserve, and those which tend to change the condition of the earth's surface, are never in equilibrio; the latter are, in all cases, the most powerful, and, in respect of the former, are like living in comparison of dead forces. Hence the law of decay is one which suffers no exception: The elements of all bodies were once loose and unconnected, and to the same state nature has appointed that they should all return.

It affords no presumption against the reality of this progress, that, in respect of man, it is too slow to be immediately perceived. The utmost portion of it to which our experience can extend, is evanescent, in comparison with the whole, and must be regarded as the momentary increment of a vast progression, circumscribed by no other limits than the duration of the world. Time performs the office of integrating the infinitesimal parts of which this progression is made up; it collects them into one sum, and produces from them an amount greater than any that can be assigned.

While on the surface of the earth so much is every where going to decay, no new production of mineral substances is found in any region accessible to man. The instances of what are called petrifactions, or the formation of stony substances by means of water, which we sometimes observe, whether they be ferruginous concretions, or calcareous, or, as happens in some rare cases, siliceous stalactites, are too few in number and too inconsiderable in extent, to be deemed material exceptions to this general rule. The bodies thus generated, also, are no sooner formed, than they become subject to waste and dissolution, like all the other hard substances in nature; so that they but retard for a while the progress by which they are all resolved into dust, and sooner or later committed to the bosom of the deep.

We are not, however, to imagine, that there is nowhere any means of repairing this waste; for, on comparing the conclusion at which we are now arrived, viz. that the present continents are all going to decay, and their materials descending into the ocean, with the proposition first laid down, that these same continents are composed of materials which must have been collected from the decay of former rocks, it is impossible not to recognise two corresponding steps of the same progress; of a progress, by which mineral substances are subjected to the same series of changes, and alternately wasted away and renovated. In the same manner, as the present mineral substances derive their origin from substances similar to themselves; so, from the land now going to decay, the sand and gravel forming on the sea shore, or in the beds of rivers; from the shells and corals, which in such enormous quantities are every day accumulated in the bosom of the sea; from the drift wood, and the multitude of vegetable and animal remains continually deposited in the ocean: from all these we cannot doubt, that strata are now forming in those regions, to which nature seems to have confined the powers of mineral reproduction; from which, after being consolidated, they are again destined to emerge, and to exhibit a series of changes similar to the past.

How often these vicissitudes of decay and renovation have been repeated, is not for us to determine; they constitute a series, of which, as the author of this theory has remarked, we neither see the beginning nor the end; a circumstance that accords well with what is known concerning other parts of the economy of the world. In the continuation of the different species of animals and vegetables that inhabit the earth, we discern neither a beginning nor an end; and, in the planetary motions, where geometry has carried the eye so far both into the future and the past, we discover no mark, either of the commencement or the termination of the present order. It is unreasonable, indeed, to suppose, that such marks should any where exist. The Author of nature has not given laws to the universe, which like the institutions of men, carry in themselves the elements of their own destruction. He has not permitted, in his works, any symptom of infancy or of old age, or any sign by which we may estimate either their future or their past duration. He may put an end, as he no doubt gave a beginning, to the present system, at some determinate period; but we may safely conclude, that this great catastrophe will not be brought about by any of the laws now existing, and that it is not indicated by any thing which we perceive.

To assert, therefore, that, *in the economy of the world, we see no mark, either of a beginning or an end,* is very different from affirming, that the world had no beginning, and will have no end. The first is a conclusion justified by common sense, as well as sound philosophy; while the second is a presumptuous and unwarrantable assertion, for which no reason from experience or analogy can ever be assigned. Dr. Hutton might, therefore, justly complain of the uncandid criticism, which, by substituting the one of these assertions for the other, endeavoured to load his theory with the reproach of atheism and impiety. Mr. Kirwan, in bringing forward this harsh and ill-founded censure, was neither animated by the spirit, nor guided by the maxims of true philosophy. By the spirit of philosophy, he must have been induced to reflect that such poisoned weapons as he was preparing to use, are hardly ever allowable in scientific contest, as having a less direct tendency to overthrow the system, than to hurt the person of an adversary, and to wound, perhaps incurably, his mind, his reputation, or his peace. By the maxims of philosophy, he must have been reminded, that, in no part of the history of nature, has any mark been discovered, either of the beginning or the end of the present order; and that the geologist sadly mistakes, both the object of his science and the limits of his understanding, who thinks it his business to explain the means employed by Infinite Wisdom for establishing the laws which now govern the world.

By attending to these obvious considerations, Mr. Kirwan would have avoided a very illiberal and ungenerous proceeding; and, however he might have differed from Dr. Hutton as to the truth of his opinions, he would not have censured their tendency with such rash and unjustifiable severity.

But, if this author may be blamed for wanting the temper, or neglecting the rules of philosophic investigation, he is hardly less culpable, for having so slightingly considered the scope and spirit of a work which he condemned so freely. In that work, instead of finding the world represented as the result of necessity or chance, which might be looked for, if the accusations of atheism or impiety were well founded, we see everywhere the utmost attention to discover, and the utmost disposition to admire, the instances of wise and beneficent design manifested in the structure, or economy of the world. The enlarged views of these, which his geological system afforded, appeared to Dr. Hutton himself as its most valuable result. They were the parts of it which he contemplated with greatest delight; and he would have been less flattered, by being told of the ingenuity and originality of his theory, than of the addition which it had made to our knowledge of final causes. It was natural, therefore, that he should be hurt by an attempt to accuse him of opinions, so different from those which he had always taught; and if he answered Mr. Kirwan's attack with warmth or asperity, we must ascribe it to the indignation excited by unmerited reproach.

But to return to the natural history of the earth: Though there be in it no data, from which the commencement of the present order can be ascertained, there are many by which the existence of that order may be traced back to an antiquity extremely remote. The beds of primitive schistus, for instance, contain sand, gravel, and other materials, collected, as already shown, from the dissolution of mineral bodies; which bodies, therefore, must have existed long before the oldest part of the land was formed. Again, in this gravel we sometimes find pieces of sandstone, and of other compound rocks, by which we are of course carried back a step farther, so as to reach a system of things, from which the present is the third in succession; and this may be considered as the most ancient epoch of which any memorial exists in the records of the fossil kingdom.

Next in the order of time to the consolidation of the primary strata, we must place their elevation, when, from being horizontal, and at the bottom of the sea, they were broken, set on edge, and raised to the surface. It is even probable, as formerly observed, that to this succeeded a depression of the same strata, and a second elevation, so that they have twice visited the superior, and twice the inferior regions. During the second immersion, were formed, first, the great bodies of pudding-stone, that in so many instances lie immediately above them, and next were deposited the strata that are strictly denominated secondary.

The third great event was the raising up of this compound body of old and new strata from the bottom of the sea, and forming it into the dry land, or the continents, as they now exist. Contemporary with this, we must suppose the injection of melted matter among the strata, and the consequent formation of the crystallized and unstratified rocks, namely, the granite, metallic veins, and veins of porphyry and whinstone. This, however, is to be considered as embracing a period of great duration; and it must always be recollected, that veins are found of a very different formation; so that when we speak generally, it is perhaps impossible to state anything more precise concerning their antiquity, than that they are posterior to the strata, and that the veins of whinstone seem to be the most recent of all, as they traverse every other.

In the fourth place, with respect to time, we must class the facts that regard the detritus and waste of the land, and must carefully distinguish them from the more ancient phenomena of the mineral kingdom. Here we are to reckon the shaping of all the present inequalities of the surface; the formation of hills of gravel, and of what have been called tertiary strata, consisting of loose and unconsolidated materials; also collections of shells not mineralized, like those in Touraine; such petrifactions as those contained in the rock of Gibraltar, on the coast of Dalmatia, and in the caves of Bayreuth. The bones of land animals found in the soil, such as those of Siberia, or North America, are probably more recent than any of the former.

These phenomena, then, are all so many marks of the lapse of time, among which the principles of geology enable us to distinguish a certain order, so that we know some of them to be more, and others to be less distant, but without being able to ascertain, with any exactness, the proportion of the immense intervals which separate them. These intervals admit of no comparison with the astronomical measures of time, they cannot be expressed by the revolutions of the sun or of the moon; nor is there any synchronism between the most recent epochs of the mineral kingdom, and the most ancient of our ordinary chronology.

On what is now said is grounded another objection to Dr. Hutton's theory, namely, that the high antiquity ascribed by it to the earth, is inconsistent with that system of chronology which rests on the authortiy of the Sacred Writings. This objection would no doubt be of weight, if the high antiquity in question were not restricted merely to the globe of the earth, but were also extended to the human race. That the origin of mankind does not go back beyond six or seven thousand years, is a position so involved in the narrative of the Mosaic books, that anything inconsistent with it would no doubt stand in opposition to the testimony of those ancient records. On this subject, however, geology is silent; and the history of arts and sciences, when traced as high as any authentic monuments extend, refers the beginnings of civilization to a date not very different from that which has just been mentioned, and infinitely within the limits of the most recent of the epochs, marked by the physical revolutions of the globe.

But on the other hand, the authority of the Sacred Books seems to be but little interested in what regards the mere antiquity of the earth itself; nor does it appear that their language is to be understood literally concerning the age of that body, any more than concerning its figure or its motion. The theory of Dr. Hutton stands here precisely on the same footing with the system of Copernicus; for there is no reason to suppose that it was the purpose of revelation to furnish a standard of geological, any more than of astronomical science. It is admitted, on all hands, that the Scriptures are not intended to resolve physical questions, or to explain matters in no way related to the morality of human actions; and if, in consequence of this principle, a considerable latitude of interpretation were not allowed, we should continue at this moment to believe that the earth is flat; that the sun moves around the earth;

and that the circumference of the circle is no more than three times its diameter.

It is but reasonable, therefore, that we should extend to the geologist the same liberty of speculation, which the astronomer and mathematician are already in possession of; and this may be done, by supposing that the chronology of Moses relates only to the human race. This liberty is not more necessary to Dr. Hutton than to other theorists. No ingenuity has been able to reconcile the natural history of the globe with the opinion of its recent origin; and accordingly the cosmologies of Kirwan and Deluc, though contrived with more mineralogical skill, are not less forced and unsatisfactory than those of Burnet and Whiston.

It is impossible to look back on the system which we have thus endeavoured to illustrate, without being struck with the novelty and beauty of the views which it sets before us. The very plan and scope of it distinguish it from all other theories of the earth, and point it out as a work of great and original invention. The sole object of such theories has hitherto been, to explain the manner in which the present laws of the mineral kingdom were first established, or began to exist, without treating of the manner in which they now proceed, and by which their continuance is provided for. The authors of these theories have accordingly gone back to a state of things altogether unlike the present, and have confined their reasonings, or their fictions, to a crisis which has never existed but once, and which can never return. Dr. Hutton, on the other hand, has guided his investigation by the philosophical maxim, *Causam naturalem et assiduam quaerimus, non raram et fortuitam.* His theory, accordingly, presents us with a system of wise and provident economy, where the same instruments are continually employed, and where the decay and renovation of fossils being carried on at the same time in the different regions allotted to them, preserve in the earth the conditions essential for the support of animal and vegetable life. We have been long accustomed to admire that beautiful contrivance in nature, by which the water of the ocean, drawn up in vapour by the atmosphere, imparts, in its descent, fertility to the earth, and becomes the great cause of vegetation and of life; but now we find, that this vapour not only fertilizes, but creates the soil; prepares it from the solid rock, and, after employing it in the great operations of the surface, carries it back into the regions where all its mineral characters are renewed. Thus, the circulation of moisture through the air, is a prime mover, not only in the annual succession of the seasons, but in the great geological cycle, by which the waste and reproduction of entire continents is circumscribed. Perhaps a more striking view than this, of the wisdom that presides over nature, was never presented by any philosophical system, nor a greater addition ever made to our knowledge of final causes. It is an addition which gives consistency to the rest, by proving that equal foresight is exerted in providing for the whole and for the parts, and that no less care is taken to maintain the constitution of the earth, than to preserve the tribes of animals and vegetables which dwell on its surface. In a word, it is the peculiar excellence of this theory, that it ascribes to the phenomena of geology an order similar to that which exists in the provinces of nature with which we are best acquainted; that it produces seas and continents, not by accident, but by the operation of regular and uniform causes; that it makes the decay of one part subservient to the restoration of another, and gives stability to the whole, not by perpetuating individuals, but by reproducing them in succession.

Again, in the details of this theory, and the ample deduction on which it is founded, we meet with many facts and observations, either entirely new, or hitherto very imperfectly understood. Thus, the veins which produce from masses of granite, and penetrate the incumbent schistus, had either escaped the observation of former mineralogists, or the importance of the phenomena had been entirely overlooked. Dr. Hutton has described the appearances with great accuracy, and drawn from them the most interesting conclusions. At the junction of the primary and secondary strata, the facts which he has noted had been observed by others; but no one, I think, had so fully understood the language which they speak, or had so clearly perceived the consequences that necessarily follow from them. He is the first who distinctly pointed out the characters which distinguish whinstone from lava, and who explained the true relation that subsists between these substances. He also discovered the induration of the strata, in contact with veins of whin, and the charring of the coal in their vicinity. His theory also enabled him to determine the affinity of whinstone and granite to one another, and their relation to the other great bodies of the mineral kingdom.

To the observations of the same excellent geologist we are indebted for the knowledge of the general and important fact, that all the hard substances of the mineral kingdom, when elevated into the atmosphere, have a tendency to decay, and are subject to a disintegration and waste, to which no limit can be set but that of their entire destruction; that no provision is made on the surface for repairing this waste, and that there no new fossil is produced; that the formation of all the varied scenery which the surface of the earth exhibits, depends on the operation of causes, the momentary exertions of which are familiar to us, though we knew not before the effects which their accumulated action was able to produce. These are facts in the natural history of the earth, the discovery of which is due to Dr. Hutton; and, should we lay all further speculation aside, and consider the theory of the earth as a work too great to be attempted by man, we must still regard the phenomena and laws just mentioned, as forming a solid and valuable addition to our knowledge.

If we would compare this theory with others, as to the invisible agents which it employs, we must consider, that fire and water are the two powers which all of them must make use of, so that they can differ only by the way in which they combine these powers. In Dr. Hutton's system, water is first employed to deposit and arrange, and then fire to consolidate, mineralize, and lastly, to elevate the strata; but, with respect to the unstratified or crystallized substances, the action of fire only is recognised. The system having least affinity to this is the Neptunian, which ascribes the formation of all minerals to the action of water alone, and extends this hypothesis even to the unstratified rocks. Here, therefore, the action of fire is entirely excluded; and the Neptunists have certainly made a great sacrifice to the love of truth, or of paradox, in rejecting the assistance of so powerful an auxiliary.

In the systems which employ the agency of the latter element, we are to look for a greater resemblance to that of Dr. Hutton, though many and great marks of distinction are easily perceived. In the cosmologies, for example, of Leibnitz and Buffon, fire and water are both employed, as well as in this; but they are employed in a reverse order. These philosophers introduce the action of fire first, and then the action of water, which is to invert the order of nature altogether, as the consolidation of the rocks must be posterior to their stratification. Indeed, the theory of Buffon is singularly defective: besides inverting the order of the two great operations of consolidation and stratification, and, of course, giving no real explanation of the latter, it gives no account of the elevation, or highly inclined position of the strata; it makes no distinction between stratified and unstratified bodies, nor does it offer any but the most unsatisfactory explanation of the inequalities of the earth's surface. This system, therefore, has but a very distant resemblance to the Huttonian theory.

The system of Lazzaro Moro has been remarked as approaching nearer to this theory than any other; and it is certain that one very important principle is common to them both. The theory of the Italian geologist was chiefly directed to the explanation of the remains of marine animals, which are found in mountains far from the sea; and it appears to have been suggested to him by the phenomena of the *Campi Phlegraei,* and by the production of the new island of Santorini in the Archipelago. He accordingly supposes that the islands and continents have been all raised up, like the above mentioned island, from the bottom of the sea, by the force of volcanic fire: that these fires began to burn under the bottom of the ocean, soon after the creation of the world, when as yet the ocean covered the whole earth; that they at first elevated a portion of the land; and in this primitive land no shells are found, as the original ocean was destitute of fish. The volcanoes continuing to burn, under the sea, after the creation of animated nature, the strata that were then raised up by their action were full of shells and other marine objects; and, from the violence with which they were elevated, arose the contortions and inclined position which they frequently possess.

This system is imperfect, as it makes no peculiar provision for the consolidation of the strata, which, according to it, as well as the Neptunian system, must be ascribed to the action, not of fire, but of water. No account is given of the mineralization of the shells found in the strata, or of the difference between them and the shells found loose at the bottom of the sea; and no distinction is made between stratified and unstratified substances. But, with all this, Lazzaro Moro has certainly the merit of having perceived, that some other power than that which deposited the strata, must have been employed for their elevation, and that they have endured the action of a disturbing force.

From this comparison it appears that Dr. Hutton's theory is sufficiently distinct, even from the theories which approach to it most nearly, to merit, in the strictest sense, the appellation of new and original. There are indeed few inventions or discoveries, recorded in the history of science, to which nearer approaches were not made before they were fully unfolded. It therefore very well deserves to be distinguished by a particular name; and, if it behooves us to follow the analogy observed in the names of the two great systems, which at present divide the opinions of geologists, we may join Mr. Kirwan in calling this the Plutonic system. For my own part, I would rather have it characterized by a less splendid, but juster name, that of the Huttonian theory.

The circumstance, however, which gives to this theory its peculiar character, and exalts it infinitely above all others, is the introduction of the principle of pressure, to modify the effects of heat when applied at the bottom of the sea. This is, in fact, the key to the great enigma of the mineral kingdom, where, while one set of phenomena indicates the action of fire, another set, equally remarkable, seem to exclude the possibility of that action, by presenting us with mineral substances, in such a state as they could never have been brought into by the operation of the fires we see at the surface of the earth. These two classes of phenomena are reconciled together, by admitting the power of compression to confine the volatile parts of bodies when heat is applied to them, in many instances, to undergo fusion, instead of being calcined or dissipated by burning or inflammation. In this hypothesis, which some affect to consider as a principle gratuitously assumed, there appears to me nothing but a very fair and legitimate generalization of the properties of heat. Combustion and inflammation are chemical processes, to which other conditions are required, beside the presence of a high temperature. The state of the mineral regions makes it reasonable to presume, that these conditions are wanting in the bowels of the earth, where, of consequence, we have a right to look for nothing but expansion and fusion, the only operations which seem essential to heat, and inseparable from the application of it, in certain degrees to certain substances. Though this principle, therefore, had no countenance from analogy, the admirable simplicity, and the unity, which it introduces into the phenomena of geology, would sufficiently justify the application of it to the theory of the earth.

As another excellence of this theory, I may, perhaps, be allowed to remark, that it extends its consequences beyond those to which the author of it has himself adverted, and that it affords, which no geological theory has yet done, a satisfactory explanation of the spheroidal figure of the earth.

Yet, with all these circumstances of originality, grandeur, and simplicity in its favour, with the addition of evidence as demonstrative as the nature of the subject will admit, this theory has many obstacles to overcome, before it meets the general approbation. The greatness of the objects which it sets before us alarms the imagination; the powers which it supposes to be lodged in the subterraneous regions; a heat which has subdued the most refractory rocks, and has melted beds of marble and quartz; an expansive force which has folded up, or broken the strata, and raised whole continents from the bottom of the sea; these are things with which, however certainly they may be proved, the mind cannot soon be familiarized. The change and movement also, which this theory ascribes to all that the senses declare to be most unalterable, raise up against it the same prejudices which formerly opposed the belief in the true system of the world; and it affords a curious proof, how little such prejudices are subject to vary, that as Aristarchus, an ancient follower of that system, was charged with impiety for moving the everlasting Vesta from her place, so Dr. Hutton, nearly on the same ground, has been subjected to the very same accusation. Even the length of time which this theory regards as necessary to the revolutions of the globe, is looked on as belonging to the marvelous; and man, who finds himself constrained by the want of time, or of space, in almost all his undertakings, forgets, that in these, if in anything, the riches of nature reject all limitations.

The evidence which must be opposed to all these causes of incredulity, cannot be fully understood without much study and attention. It requires not only a careful examination of particular instances, but comprehensive views of the whole phenomena of geology; the comparison of things very remote with one another; the interpretation of the obscure by the luminous, and of the doubtful by the decisive appearances. The geologist must not content himself with examining the insulated specimens of his cabinet, or with pursuing the nice subtleties of mineralogical arrangement; he must study the relation of fossils, as they actually exist; he must follow nature into her wildest and most inaccessible abodes; he must select, for the places of his observations, those points from which the variety and gradation of her works can be most extensively and accurately explored. Without such an exact and comprehensive survey, his mind will hardly be prepared to relish the true theory of the earth. *"Naturae enim vis atque majestas omnibus momentis fide caret, si quis modo partes atque non, totam complectatur animo."*

If indeed this theory of the earth is, as we suppose it to be, the lapse of time must necessarily remove all objections to it, and the progress of science will only develop its evidence more fully. As it stands at present, though true, it must be still imperfect; and it cannot be doubted, that the great principles of it, though established on an immovable basis, must yet undergo many modifications, requiring to be limited, in one place, or to be extended, in another. A work of such variety and extent cannot be carried to perfection by the efforts of an indivual. Ages may be required to fill up the bold outline which Dr. Hutton has traced with so masterly a hand; to detach the parts more completely from the general mass; to adjust the size and position of the subordinate members; and to give to the whole piece the exact proportion and true colouring of nature.

This, however, in length of time, may be expected from the advancement of science, and from the mutual assistance which parts of Knowledge, seemingly most remote, often afford to one another. Not only may the observations of the mineralogist, in tracts yet unexplored, complete the enumeration of geological facts; and the experiments of the chemist, on subjects not yet subjected to his analysis, afford a more intimate acquaintance with the nature of fossils, and a measure of the power of those chemical agents to which this theory ascribes such vast effects; but also from other sciences, less directly connected with the natural history of the earth, much information may be received. The accurate geographical maps and surveys which are now making; the soundings; the observation of the currents; the barometrical measurements, may all combine to ascertain the reality, and to fix the quantity of those changes which terrestrial bodies continually undergo. Every new improvement in science affords the means of delineating more accurately the face of nature as it now exists, and of transmitting, to future ages, an account, which may be compared with the face of nature as it shall then exist. If, therefore, the science of the present times is destined to survive the physical revolutions of the globe, the Huttonian Theory may be confirmed by historical record; and the author of it will be remembered among the illustrious few, whose systems have been verified by the observations of succeeding ages, supported by facts unknown to themselves, and established by the decisions of a tribunal, slow, but infallible, in distinguishing between truth and falsehood.

HERSCHEL

Sir William Herschel was born in Hanover, Germany, November 15, 1738. He was the son of a bandmaster and was specially educated in music. At fourteen he was forced to earn his own living and joined the band of the Hanoverian Guards. This took him to England in 1759. He later became organist at Bath. All this time he studied the languages and mathematics by himself. He grew to be much interested in the science of music and was led from this to take interest in the fabled "music of the spheres."

Even an ordinary telescope was beyond his means, and he at length, after some 200 failures, succeeded in constructing specula for a telescope that he considered satisfactory. In 1781 with one of his own telescopes he discovered the planet Uranus, thought at first to be a comet. Honors now fell fast upon him. He discovered two of the satellites of Uranus, two more of Saturn, and that the moon is without atmosphere; noted many of the binary stars; made the great inference from the movements of the stars that the whole solar system is rushing toward the constellation of Hercules; and pointed out many nebulous stars, which led directly to the nebular theory of the universe.

He died in 1822. His one son, Sir John Herschel, became also a famous astronomer.

THE DISCOVERY OF URANUS

Account of a Comet

On Tuesday, the 13th of March, 1781, between 10 and 11 in the evening, while examining the small stars in the neighborhood of H Geminorum, I perceived one that appeared visibly larger than the rest: being struck with its uncommon magnitude, I compared it to H Geminorum and the small star in the quartile between Auriga and Gemini, and finding it so much larger than either of them, suspected it to be a comet. I was then engaged in a series of observations on the parallax of the fixed stars, which I hope soon to have the honour of laying before the R. S.; and those observations requiring very high powers, I had ready at hand several magnifiers of 227, 460, 932, 1536, 2010, &c., all of which I have successfully used on that occasion. The power I had on when I first saw the comet was 227. From experience I knew that the diameters of the fixed stars are not proportionally magnified with higher powers, as the planets are; I therefore now put on the powers of 460 and 932, and found the diameter of the comet increased in proportion to the power, as it ought to be, on a supposition of its not being a fixed star, while the diameters of the stars to which I compared it, were not increased in the same ratio. Also, that the comet being magnified much beyond what its light would admit of, appeared hazy and ill-defined with these great powers, while the stars preserved that lustre and distinctness which from many thousand observations I knew they would retain. The sequel has shown that my surmises were well founded, this proving to be the comet we have lately observed.

Mr. H. reduced all his observations on this comet to three tables. The first contains the measures of the gradual increase of the comet's diameter. The micrometers he used, when every circumstance is favourable will measure extremely small angles, such as do not exceed a few seconds, true to 6, 8, or 10 thirds at most; and in the worst situations true to 20 or 30 thirds; he therefore gave the measures of the comet's diameter in seconds and thirds. The first table, containing the measures of the comet's diameter, shows that, from March 17 to April 18, the apparent diameter had increased from 2″ 53‴ to 5′ 20‴.

The second table contains the comet's distances from several telescopic fixed stars from March 13 till April 19, and those distances expressed in minutes, seconds and thirds. And the third table contains the comet's angle of position with regard to the parallel of declination of the same stars measured by a micrometer; by which means its places and apparent path might be determined.—Trans. Roy. Phil. Soc.

ON THE NAME OF THE NEW PLANET

By the observations of the most eminent astronomers in Europe it appears that the new star, which I had the honour of pointing out to them in March, 1781, is a primary planet of our solar system.* A body so nearly related to us by its similar condition and situation, in the unbounded expanse of the starry heavens, must often be the subject of conversation, not only of astronomers, but of every lover of science in general. This consideration, then, makes it necessary to give it a name, by which it may be distinguished from the rest of the planets and fixed stars. In the fabulous ages of ancient times the appellations of Mercury, Venus, Mars, Jupiter, and Saturn, were given to the planets, as being the names of their principal heroes and divinities. In the present more philosophical era, it would hardly be allowable to have recourse to the same method, and call on Juno, Apollo, Pallas or Minerva, for a name to our new heavenly body. The first consideration in any particular event, or remarkable incident, seems to be its chronology; if in any future age it should be asked, when this last-found planet was discovered it would be a very satisfactory answer to say, "In the reign of King George the Third." As a philosopher, then, the name of Georgium Sidus presents itself to me, as an appellation which will conveniently convey the information of the time and country where and when it was brought to view.

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* The observations of this new planet, at first suspected to be a comet, are abridged at p. 154, of this volume. Dr. Herschel, the discoverer, here calls it the Georgium Sidus, or Georgian planet, in honour of his Majesty; by which name it is commonly distinguished in this country.

ON NEBULOUS STARS, PROPERLY SO CALLED

In one of his late examinations of a space in the heavens, which he had not reviewed before, Dr. H. discovered a star of about the eighth magnitude, surrounded with a faintly luminous atmosphere, of a considerable extent. The phenomenon was so striking that he could not help reflecting on the circumstance that attended it, which appeared to be of a very instructive nature, and such as might lead to inferences which will throw a considerable light on some points relating to the construction of the heavens.

Cloudy or nebulous stars have been mentioned by several astronomers; but this name ought not to be applied to the objects which they have pointed out as such; for, on examination, they proved to be either mere clusters of stars, plainly to be distinguished with his large instru-

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But, in other countries it is often called by other names; as Ouranus, Uranius, Herschel, &c. Its Astronomical mark, or character is H. By later observations and calculations it has been determined that the diameter of this planet is about 35,109 miles, or 4 4-10 times that of the earth; its distance from the sun 1800 millions of miles, or above 19 times the earth's distance; that the period of its revolution in its orbit round the sun, is 83 years, 140 days, 17 hours. Dr. Herschel has also discovered 6 satellites or moons belonging to this planet, whose orbits are nearly perpendicular to the plane of the ecliptic; and they all perform their revolutions in their orbits contrary to the order of the signs, that is, their real motion is retrograde.—Original note.

ments, or such nebulous appearances as might be reasonably supposed to be occasioned by a multitude of stars at a vast distance. The milky way itself consists entirely of stars, and by imperceptible degrees he was led on from most evident congeries of stars to other groups in which the lucid points were smaller, but still very plainly to be seen; and from them to such wherein they could but barely be suspected, till he arrived at last to spots in which no trace of a star was to be discerned. But then the gradations to these later were by such well-connected steps as left no room for doubt but that all these phenomena were equally occasioned by stars, variously dispersed in the immense expanse of the universe.

When Dr. H. pursued these researches, he was in the situation of a natural philosopher who follows the various species of animals and insects from the height of their perfection down to the lowest ebb of life; when, arriving at the vegetable kingdom, he can scarcely point out to us the precise boundary where the animal ceases and the plant begins; and may even go so far as to suspect them not to be essentially different. But recollecting himself, he compares, for instance, one of the human species to a tree, and all doubt of the subject vanishes before him. In the same manner we pass through gentle steps from a coarse cluster of stars, such as the Pleiades, the Præserpe, the milky way, the cluster in the Crab, the nebula in Hercules, that near the preceding hip of Bootis, the 17th, 38th, 41st of the 7th class of his catalogues, the 10th, 20th, 35th of the 6th class, the 33d, 48th, 213th of the 1st, the 12th, 150th, 756th of the 2d, and the 18th, 140th, 725th of the 3d, without any hesitation, till we find ourselves brought to an object such as the nebula in Orion, where we are still inclined to remain in the once adopted idea, of stars exceedingly remote, and inconceivably crowded, as being the occasion of that remarkable appearance. It seems, therefore, to require a more dissimilar object to set us right again. A glance like that of the naturalist, who casts his eye from the perfect animal to the perfect vegetable, is wanting to remove the veil from the mind of the astronomer. The object mentioned above is the phenomenon that was wanting for this purpose. View, for instance, the 19th cluster of the 6th class, and afterwards cast your eye on this cloudy star, and the result will be no less decisive than that of the naturalist alluded to. Our judgment will be, that the nebulosity about the star is not of a starry nature.

But that we may not be too precipitate in these new decisions, let us enter more at large into the various grounds which induced us formerly to surmise, that every visible object, in the extended and distant heavens, was of the starry kind, and collate them with those which now offer themselves for the contrary opinion. It has been observed, on a former occasion, that all the smaller parts of other great systems, such as the planets, their rings and satellites, the comets, and such other bodies of the like nature as may belong to them, can never be perceived by us, on account of the faintness of light reflected from small opaque objects: in the present remarks, therefore, all these are to be entirely set aside.

A well connected series of objects, such as mentioned above, has led us to infer that all nebulæ consist of stars. This being admitted, we were authorized to extend our analogical way of reasoning a little further. Many of the nebulæ had no other appearance than that whitish cloudiness, on the blue ground on which they seemed to be projected; and why the same cause should not be assigned to explain the most extensive nebulosities, as well as those that amounted only to a few minutes of a degree in size, did not appear. It could not be inconsistent to call up a telescopic milky way, at an immense distance, to account for such a phenomenon; and if any part of the nebulosity seemed detached from the rest, or contained a visible star or two, the probability of seeing a few near stars, apparently scattered over the far distant regions of myriads of sidereal collections, rendered nebulous by their distance, would also clear up these singularities.

In order to be more easily understood in his remarks on the comparative disposition of the heavenly bodies, Dr. H. mentions some of the particulars which introduced the ideas of connection and disjunction: for these, being properly founded on an examination of objects that may be reviewed at any time, will be of considerable importance to the validity of what we may advance with regard to the lately discovered nebulous stars. On June 27, 1786, he saw a beautiful cluster of very small stars of various sizes, about 15′ in diameter, and very rich of stars. On viewing this object, it is impossible to withhold our assent to the idea which occurs, that these stars are connected so far with one another as to be gathered together, within a certain space, of little extent when compared to the vast expanse of the heavens. As this phenomenon has been repeatedly seen in a thousand cases, Dr. H. thinks he may justly lay great stress on the idea of such stars being connected. On September 9, 1779, he discovered a very small star near *ε* Bootis. The question here occurring, whether it had any connection with *ε* or not, was determined in the negative; for, considering the number of stars scattered in a variety of places, it is very far from being uncommon, that a star at a great distance should happen to be nearly in a line drawn from the sun through *e*, and thus constitute the observed double star. September 7, 1782, when Dr. H. first saw the planetary nebula near *v* Aquarii, he pronounced it to be a system whose parts were connected together. Without entering into any kind of calculation, it is evident, that a certain degree of light within a very small space, joined to the particular shape this object presents to us, which is nearly round, and even in its deviation consistent with regularity, being a little elliptical, ought naturally to give us the idea of a conjunction in the things that produce it. And a considerable addition to this argument may be derived from a repetition of the same phenomenon, in nine or ten more of a similar construction.

When Dr. H. examined the cluster of stars, following the head of the Great Dog, he found on March 19, 1786, that there was within this cluster a round, resolvable nebula, of about 2′ in diameter, and nearly an equal degree of light throughout. Here, considering that the cluster was free from nebulosity in other parts, and that many such clusters, as well as such nebulæ, exist in divers parts of the heavens, it seemed very probable that the nebula was unconnected with the cluster; and that a similar reason would as easily account for this appearance as it had resolved the phenomenon of the double star near *e* Bootis; that is, a casual situation of our sun and the two other objects nearly in a line. And though it may be rather more remarkable, that this should happen with two compound systems, which are not by far so numerous as single stars, we have, to make up for this singularity, a much larger space in which it may take place, the cluster being of a very considerable extent.

On February 15, 1786, Dr. H. discovered that one of his planetary nebulæ had a spot in the centre, which was more luminous than the rest, and with long attention, a very bright, round, well-defined centre became visible. He remained not a single moment in doubt, but that the bright centre was connected with the rest of the apparent disc. October 6, 1785, he found a very bright, round nebula, of about 1½′ in diameter. It has a large, bright nucleus in the middle, which is undoubtedly connected with the luminous parts about it. And though we must confess, that if this phenomenon, and many more of the same nature, recorded in the catalogues of nebulæ, consist of clustering stars, we find ourselves involved in some difficulty to account for the extraordinary condensation of them about the centre; yet the idea of a connection between the outward parts and these very condensed ones within, is by no means lessened on that account.

There is a telescopic milky way, which Dr. H. has traced out in the heavens in many sweeps made from the year 1783 to 1789. It takes up a space of more than 60 square degrees of the heavens, and there are thousands of stars scattered over it: among others, four that form a trapezium, and are situated in the well known nebula of Orion, which is included in the above extent. All these stars, as well as the four mentioned, he takes to be entirely unconnected with the nebulosity which involves them in appearance. Among them is also *d* Orionis, a cloudy star, improperly so called by former astronomers; but it does not seem to be connected with the milkiness any more than the rest.

Dr. H. now comes to some other phenomena, that, from their singularity, merit undoubtedly a very full discussion. Among the reasons which induced us to embrace the opinion, that all very faint milky nebulosity ought to be ascribed to an assemblage of stars is, that we could not easily assign any other cause of sufficient importance for such luminous appearances, to reach us at the immense distance we must suppose ourselves to be from them. But if an argument of considerable force should now be brought forward, to show the existence of luminous matter, in a state of modification very different from the construction of a sun or star, all objections, drawn from our incapacity of accounting for new phenomena on old principles, he thinks, will lose their validity.

Hitherto Dr. H. has been showing, by various instances in objects whose places are given, in what manner we may form ideas of connection, and its contrary, by an attentive inspection of them only; he now relates a series of observations, with remarks on them as they are delivered, from which he afterwards draws a few simple conclusions, that seem to be of considerable importance.

October 16, 1784. A star of about the ninth magnitude, surrounded by a milky nebulosity, or chevelure, of about 3′ in diameter. The nebulosity is very faint, and a little extended or elliptical, the extent being not far from the meridian, or a little from north preceding to south following. The chevelure involves a small star, which is about $1\frac{1}{2}'$ north of the cloudy star; other stars of equal magnitude are perfectly free from this appearance. (R. A. 5h 57m 4s. P. D. 96° 22′). His present judgment concerning this remarkable object is, that the nebulosity belongs to the star which is situated in its centre. The small one, on the contrary, which is mentioned as involved, being one of many that are profusely scattered over this rich neighbourhood, he supposes to be quite unconnected with this phenomenon. A circle of 3′ in diameter is sufficiently large to admit another small star, without any bias to the judgment he formed concerning the one in question. It must appear singular, that such an object should not have immediately suggested all the remarks contained in this paper; but about things that appear new we ought not to form opinions too hastily, and his observations on the construction of the heavens were then but entered on. In this case, therefore, it was the safest way to lay down a rule not to reason on the phenomena that might offer themselves, till he should be in possession of a sufficient stock of materials to guide his researches.

October 16, 1784. A small star of about the 11th or 12th magnitude, very faintly affected with milky nebulosity; other stars of the same magnitude were perfectly free from this appearance. Another observation mentions five or six small stars within the space of 3 or 4′, all very faintly affected in the same manner, and the nebulosity suspected to be a little stronger about each star. But a third observation rather opposes this increase of the faintly luminous appearance. (R. A. 6h 0m 33s. P. D. 96° 13′). Here the connection between the stars and the nebulosity is not so evident as to amount to conviction; for which reason we shall pass on to the next.

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November 25, 1788. A star of about the 9th magnitude, surrounded with very faint milky nebulosity; other stars of the same size are perfectly free from that appearance. Less than 1′ in diameter. The star is either not round or double (a).

March 23, 1789. A bright, considerably well-defined nucleus, with a very faint, small, round chevelure (b). The connection admits of no doubt; but the object is not perhaps of the same nature with those called cloudy stars.

April 14, 1789. A considerable, bright, round nebula; having a large place in the middle of nearly an equal brightness; but less bright towards the margin (c). This seems rather to approach the planetary sort.

March 5, 1790. A pretty considerable star of the 9th or 10th magnitude, visibly affected with a very faint nebulosity of little extent, all around. A power of 300 showed the nebulosity of greater extent (d). The connection is not to be doubted.

March 19, 1790. A very bright nucleus, with a small, very faint chevelure, exactly round. In a low situation, where the chevelure could hardly be seen, this object would put on the appearance of an ill-defined, planetary nebula, of 6, 8 or 10" diameter (e).

November 13, 1790. A most singular phenomenon! A star of about the 8th magnitude, with a faint luminous atmosphere, of a circular form, and of about 3' in diameter. The star is perfectly in the centre, and the atmosphere is so diluted, faint, and equal throughout, that there can be no surmise of its consisting of stars; nor can there be a doubt of the evident connection between the atmosphere and the star. Another star not much less in brightness, and in the same field with the above, was perfectly free from any such appearance. This last object is so decisive in every particular, Dr. H. says, that we need not hesitate to admit it as a pattern, from which we are authorised to draw the following important consequences:

Supposing the connection between the star and its surrounding nebulosity to be allowed, we argue, that one of the two following cases must necessarily be admitted: In the first place, if the nebulosity consist of stars that are very remote, which appear nebulous on account of the small angles their mutual distances subtend at the eye, by which they will not only, as it were, run into each other, but also appear extremely faint and diluted; then, what must be the enormous size of the central point, which outshines all the rest in so superlative a degree as to admit of no comparison! In the next place, if the star be no larger than common, how very small and compressed must be those other luminous points that are the occasion of the nebulosity which surrounds the central one! As, by the former supposition, the luminous central point must far exceed the standard of what we call a star, so, in the latter, the shining matter about the centre will be much too small to come under the same denomination; we therefore either have a central body which is not a star, or have a star which is involved in a shining fluid, of a nature totally unknown to us. Dr. H. can adopt no other sentiment than the latter, since the probability is certainly not for the existence of so enormous a body as would be required to shine like a star of the eighth magnitude, at a distance sufficiently great to cause a vast system of stars to put on the appearance of a very diluted milky nebulosity.

But what a field of novelty is here opened to our conceptions! A shining fluid, of a brightness sufficient to reach us from the remote regions of a star of the 8th, 9th, 10th, or 12th magnitude, and of an extent so considerable as to take up 3, 4, 5, or 6 minutes in diameter! Can we compare it to the coruscation of the electric fluid in the aurora borealis? Or to the more magnificent cone of the zodiacal light as we see it in the spring or autumn? The latter, notwithstanding Dr. H. has observed it to reach at least 90° from the sun, is yet of so little extent and brightness, as probably not to be perceived even by the inhabitants of Saturn or the Georgian planet, and must be utterly invisible at the remoteness of the nearest fixed star.

More extensive views may be derived from this proof of the existence of a shining matter. Perhaps it has been too hastily surmised that all milky nebulosity, of which there is so much in the heavens, is owing to starlight only. These nebulous stars may serve as a clue to unravel other mysterious phenomena. If the shining fluid that surrounds them is not so essentially connected with these nebulous stars, but that it can also exist without them, which seems to be sufficiently probable, and will be examined hereafter, we may with great facility explain that very extensive, telescopic nebulosity, which, as before mentioned, is expanded over more than 60° of the heavens, about the constellation of Orion; a luminous matter accounting much better for it than clustering stars at a distance. In this case we may also pretty nearly guess at its situation, which must commence somewhere about the range of the stars of the 7th magnitude, or a little farther from us, and extend unequally in some places perhaps to the regions of those of the 9th, 10th, 11th, and 12th. The foundation for this surmise is, that not unlikely some of the stars that happen to be situated in a more condensed part of it, or that perhaps by their own attraction draw together some quantity of this fluid greater than what they are entitled to by their situation in it, will, of course, assume the appearance of cloudy stars; and many of those named are either in this stratum of luminous matter, or very near it.

It has been said above, that in nebulous stars the existence of the shining fluid does not seem to be so essentially connected with the central points that it might not also exist without them. For this opinion we may assign several reasons. One of them is the greater resemblance of the chevelure of these stars and the diffused extensive nebulosity mentioned before, which renders it highly probable that they are of the same nature. Now, if this be admitted, the separate existence of the luminous matter, or its independence of a central star, is fully proved.

We may also judge, very confidently, that the light of this shining fluid is no kind of reflection from the star in the centre; for, as we have already observed, reflected light could never reach us at the great distance we are from such objects. Besides, how impenetrable would be an atmosphere of a sufficient density to reflect so great a quantity of light! And yet we obserse, that the outward parts of the chevelure are nearly as bright as those that are close to the star; so that this supposed atmosphere ought to give no obstruction to the passage of the central rays. If therefore this matter is self-luminous, it seems more fit to produce a star by its condensation than to depend on the star for its existence.

Many other diffused nebulosities, besides that about the constellation of Orion, have been observed or suspected; but some of them are probably very distant, and run far out into space. For instance, about 5m in time preceding *x* Cygni, Dr. H. suspects as much of it as covers near 4 square degrees; and much about the same quantity 44m preceding the 125 Tauri. A space of almost 8 square degrees, 6m preceding *a* Trianguli, seems to be tinged with milky nebulosity. Three minutes preceding the 46 Eridani, strong, milky nebulosity is expanded over more than 2 square degrees. Fifty-four minutes preceding the 13th *Canum venaticorum*, and again 48m preceding the same star, the field of view affected with whitish nebulosity throughout the whole breadth of the sweep, which was 2° 39′. Four minutes following the 57 Cygni a considerable space is filled with faint, milky nebulosity, which is pretty bright in some places, and contains the 37th nebula of the 5th class, in the brightest part of it. In the neighbourhood of the 44th Piscium, very faint nebulosity appears to be diffused over more than 9 square degrees of the heavens. Now all these phenomena, as we have already seen, will admit of a much easier explanation by a luminous fluid than by stars at an immense distance.

The nature of planetary nebulæ, which has hitherto been involved in much darkness, may now be explained with some degree of satisfaction, since the uniform and very considerable brightness of their apparent disc accords remarkably well with a much condensed, luminous fluid; whereas, to suppose them to consist of clustering stars, will not so completely account for the milkiness or soft tint of their light, to produce which it would be required that the condensation of the stars should be carried to an almost inconceivable degree of accumulation. The surmise of the regeneration of stars, by means of planetary nebulæ, expressed in a former paper, will become more probable, as all the luminous matter contained in one of them, when gathered together into a body of the size of a star, would have nearly such a quantity of light as we find the planetary nebulæ to give. To prove this experimentally, we may view them with a telescope that does not magnify sufficiently to show their extent, by which means we shall gather all their light together into a point, when they will be found to assume the appearance of small stars; that is, of stars at the distance of those which we call of the 8th, 9th, or 10th magnitude. Indeed this idea is greatly supported by the discovery of a well-defined, lucid point, resembling a star, in the centre of one of them; for the argument which has been used, in the case of nebulous stars, to show the probability of the existence of luminous matter, which rested on the disparity between a bright point and its surrounding shining fluid, may here be alleged with equal justice. If the point be a generating star, the further accumulation of the already much condensed, luminous matter may complete it in time.

How far the light that is perpetually emitted from millions of suns may be concerned in this shining fluid, it might be presumptious to attempt to determine; but, notwithstanding the inconceivable subtilty of the particles of light, when the number of the emitting bodies is almost infinitely great, and the time of the continual emission indefinitely long, the quantity of emitted particles may well become adequate to the constitution of a shining fluid, or luminous matter, provided a cause can be found that may retain them from flying off, or reunite them. But such a cause cannot be difficult to guess at, when we know that light is so easily reflected, refracted, inflected and deflected; and that, in the immense range of its course, it must pass through innumerable systems, where it cannot but frequently meet with many obstacles to its rectilinear progression. Not to mention the great counteraction of the united attractive force of whole sidereal systems, which must be continually exerting their power on the particles while they are endeavouring to fly off. However, we shall lay no stress on a surmise of this kind, as the means of verifying it are wanting; nor is it of any immediate consequence to us to know the origin of the luminous matter. Let it suffice, that its existence is rendered evident, by means of nebulous stars.—The Report by Herschel in the Trans. of the Royal Phil. Soc. of London.

ON THE PROPER MOTION OF THE SUN AND SOLAR SYSTEM

That several of the fixed stars have a proper motion, is now already so well confirmed that it will admit of no further doubt. From the time this was first suspected by Dr. Halley we have had continued observations that show Arcturus, Sirius, Aldebaran, Procyon, Castor, Rigel, Altair, and many more, to be actually in motion; and considering the shortness of the time we have had observations accurate enough for the purpose, it may rather be wondered that we have already been able to find the motions of so many, than that we have not discovered like alterations in all the rest. Besides, we are well prepared to find numbers of them apparently at rest, as, on account of their immense distance, a change of place cannot be expected to become visible to us till after many ages of careful attention and close observation, though every one of them should have a motion of the same importance with Arcturus. This consideration alone would lead us strongly to suspect, that there is not, strictly speaking, one fixed star in the heavens; but many other reasons will render this so obvious, that there can hardly remain a doubt of the general motion of all the starry systems, and consequently of the solar one among the rest.

We might begin with principles drawn from the theory of attraction, which evidently oppose every idea of absolute rest in any one of the stars, when once it is known that some of them are in motion; for the change that must arise by such motion, in the value of a power which acts inversely as the squares of the distances, must be felt in all the neighbouring stars; and if these be influenced by the motion of the former, they will again affect those that are next to them, and so on until all are in motion. Now as we know that several stars, in divers parts of the heavens, do actually change their places, it will follow, that the motion of our solar systems is not a mere hypothesis; and what will give additional weight to this consideration is, that we have the greatest reason to suppose most of those very stars, which have been observed to move, to be such as are nearest to us; and therefore their influence on our situation would alone prove a powerful argument in favour of the proper motion of the sun, had it been originally at rest.

Admitting this for granted, the greatest difficulty will be, how to discern the proper motion of the sun among so many other, and variously compounded, motions of the stars. This is an arduous task indeed, which we must not hope to see accomplished in our time; but we are not to be discouraged from the attempt. Let us, at all events, says Mr. H., endeavour to lay a good foundation for those who are to come after us. I shall therefore now point out the method of detecting the direction and quantity of the supposed proper motion of the sun by a few geometrical deductions, and at the same time show by an application of them to some known facts, that we have already some reasons to guess which way the solar system is probably tending in its course.

It remains now only to make an application of this theory to some of the facts we are already acquainted with, relating to the proper motion of the stars. Astronomers have already observed what they call a proper motion in several of the fixed stars, and the same may be supposed of them all. We ought therefore to resolve that which is common to all the stars, which are found to have what has been called a proper motion, into a single real motion of the solar system, as far as that will answer the known facts; and only to attribute the proper motion of each particular star, the deviations from the general law the stars seem to follow in those movements. By Dr. Maskelyne's account of the proper motion of some principal stars, we find that Sirius, Castor, Procyon, Pollux, Regulus, Arcturus, and *a* Aquilæ, appear to have respectively the following proper motions in right ascension: -0".63; -0".28; -0".80; -0".93; 0".41; -1".40+0".57; and two of them, Sirius and Arcturus, in declination, viz. 1".20 and 2".01, both southward. Let figure 10 represent an equatorial zone, with the above mentioned stars referred to it, according to their respective right ascensions, having the solar system in its centre. Assume the direction ab from a point somewhere not far from the 77th degree of right ascension to its opposite 257th degree, and suppose the sun to move in that direction from s towards b; then will that one motion answer that of all the stars together: for if the supposition be true, Arcturus, Regulus, Pollux, Procyon, Castor and Sirius, should appear to increase. Again, suppose the sun to ascend at the same time in the same direction towards some point in the northern hemisphere, for instance, *towards the constellation of Hercules;* then will also the observed change of declination of Sirius and Arcturus be resolved into the single motion of the solar system. But lest Mr. H. should be censured for admitting so new and capital a motion on too slight a foundation, he observes, that the concurrence of those seven principal

LAPLACE

Engraving from an original picture by Nedeon.

stars cannot but give some value to an hypothesis that will simplify the celestial motions in general. We know that the sun, at the distance of the fixed star, would appear like one of them; and from analogy we conclude the stars to be suns. Now, since the apparent motions of these seven stars may be accounted for, either by supposing them to move just in the manner they appear to do, or else by supposing the sun alone to have a motion in a direction, somehow not far from that above assigned to it, we are no more authorized to suppose the sun at rest, than we are to deny the diurnal motion of the earth, except in this respect, that the proofs of the latter are very numerous, whereas the former rests only on a few though capital testimonies.

LAPLACE

Pierre Simon Laplace was born in Normandy, March 28, 1749. Before eighteen years old he was a teacher of mathematics at Beaumont, and soon afterwards gained the attention of D'Alembert by a letter to him on the principles of mathematics. From 1770 for many years he was busy with Lagrange in establishing the permanency of the solar system, accounting for its perturbations, and interactions, and showing that all these changes are periodic. His "Mechanics of the Heavens" was a gigantic exposition of the movements of the solar system. In his "System of the World" he advanced the nebular hypothesis of the origin of the universe. Most of his previous work had been done in tracing the law of gravitation throughout its many complications, in the system of planets: this latter hypothesis, though relegated to a note at the end of the "System of the World," was to give astronomy a dynamic rather than a descriptive point of view.

He tried to be a politician, but was not a good man of affairs. His ability to change with the wind, however, brought him a title of count from Napoleon, and of marquis (1817) from the restored Bourbon king. He died March 5, 1827.

THE NEBULAR HYPOTHESIS

From the preceding chapter, it appears that we have the five following phenomena to assist us in investigating the cause of the primitive motions of the planetary system. The motions of the planets in the same direction, and very nearly in the same plane; the motions of the satellites in the same direction as those of the planets; the motions of rotation of these different bodies and also of the sun, in the same direction as their motions of projection, and in planes very little inclined to each other; the small eccentricity of the orbits of the planets and satellites; finally, the great eccentricity of the orbits of the comets, their inclinations being at the same time entirely indeterminate.

Buffon is the only individual that I know of, who, since the discovery of the true system of the world, endeavoured to investigate the origin of the planets and satellites. He supposed that a comet, by impinging on the Sun, carried away a torrent of matter, which was reunited far off, into globes of different magnitudes and at different distances from this star. These globes, when they cool and become hardened, are the planets and their satellites. This hypothesis satisfies the first of the five preceding phenomena; for it is evident that all bodies thus formed should move very nearly in the plane which passes through the centre of the Sun, and through the direction of the torrent of matter which has produced them: but the four remaining phenomena appear to me inexplicable on this supposition. Inded, the absolute motion of the molecules of a planet ought to be in the same direction as the motion of the centre of gravity; but it by no means follows from this, that the motion of rotation of a planet should be also in the same direction. Thus the Earth may revolve from east to west, and yet the absolute motion of each of its molecules may be directed from west to east. This observation applies also to the revolution of the satellites, of which the direction in the same hypothesis, is not necessarily the same as that of the motion of projection of the planets.

The small eccentricity of the planetary orbits is a phenomenon, not only difficult to explain on this hypothesis, but altogether inconsistent with it. We know from the theory of central forces, that if a body which moves in a re-entrant orbit about the Sun, passes very near the body of the Sun, it will return constantly to it, at the end of each revolution.

Hence it follows that if the planets were originally detached from the Sun, they would touch it, at each return to this star; and their orbits, instead of being nearly circular, would be very eccentric. Indeed it must be admitted that a torrent of matter detached from the Sun, cannot be compared to a globe which just skims by its surface; from the impulsions which the parts of this torrent receive from each other, combined with their mutual attraction, they may, by changing the direction of their motions, increase the distances of their perihelions from the Sun. But their orbits should be extremely eccentric, or at least all the orbits would not be q. p. circular, except by the most extraordinary chance. Finally, no reason can be assigned on the hypothesis of Buffon, why the orbits of more than one hundred comets, which have been already observed, should be all very eccentric. This hypothesis, therefore, is far from satisfying the preceding phenomena. Let us consider whether we can assign the true cause.

Whatever may be its nature, since it has produced or influenced the direction of the planetary motions, it must have embraced them all within the sphere of its action; and considering the immense distance which intervenes between them, nothing could have effected this but a fluid of almost indefinite extent. In order to have impressed on them all a motion q. p. circular and in the same direction about the Sun, this fluid must environ this star, like an atmosphere. From a consideration of the planetary motions, we are therefore brought to the conclusion, that in consequence of an excessive heat, the solar atmosphere originally extended beyond the orbits of all the planets, and that it has successively contracted itself within its present limits.

In the primitive state in which we have supposed the Sun to be, it resembles those substances which are termed nebulæ, which, when seen through telescopes, appear to be composed of a nucleus, more or less brilliant, surrounded by a nebulosity, which, by condensing on its surface, transforms it into a star. If all the stars are conceived to be similarly formed, we can suppose their anterior state of nebulosity to be preceded by other states, in which the nebulous matter was more or less diffuse, the nucleus being at the same time more or less brilliant. By going back in this manner, we shall arrive at a state of nebulosity so diffuse, that its existence can with difficulty be conceived.

For a considerable time back, the particular arrangement of some stars visible to the naked eye, has engaged the attention of philosophers. Mitchel remarked long since how extremely improbable it was that the stars composing the constellation called the Pleiades, for example, should be confined within the narrow space which contains them, by the sole chance of hazard; from which he inferred that this group of stars, and the similar groups which the heavens present to us, are the effects of a primitive law of nature. These groups are a general result of the condensation of nebulæ of several nuclei; for it is evident that the nebulous matter being perpetually attracted by these different nuclei, ought at length to form a group of stars, like to that of the Pleiades. The condensation of nebulæ consisting of two nuclei, will in like manner form stars very near to each other, revolving the one about the other like to the double stars, whose respective motions have been already recognized.

But in what manner has the solar atmosphere determined the motions of rotation and revolution of the planets and satellies? If these bodies had penetrated deeply into this atmosphere, its resistance would cause them to fall on the Sun. We may therefore suppose that the planets were formed at its successive limits, by the condensation of zones of vapours, which it must, while it was cooling, have abandoned in the plane of its equator.

Let us resume the results which we have given in the tenth chapter of the preceding book. The Sun's atmosphere cannot extend indefinitely; its limit is the point where the centrifugal force arising from the motion of rotation balances the gravity; but according as the cooling contracts the atmosphere, and condenses the molecules which are near to it, on the surface of the star, the motion of rotation increases; for, in virtue of the principle of areas, the sum of the areas described by the *radius vector* of each particle of the Sun and its atmosphere, and projected on the plane of its equator, is always the same. Consequently the rotation ought to be quicker, when these particles approach to the centre of the Sun. The centrifugal force arising from this motion becoming thus greater; the point where the gravity is equal to it, is nearer to the centre of the Sun. Supposing, therefore, what is natural to admit, that the atmosphere extended at any epoch as far as this limit, it ought, according as it cooled, to abandon the molecules, which are situated at this limit, and at the successive limits produced by the increased rotation of the Sun. These particles, after being abandoned, have continued to circulate about this star, because their centrifugal force was balanced by their gravity. But as this equality does not obtain for these molecules of the atmosphere which are situated on the parallels to the Sun's equator, these have come nearer by their gravity to the atmosphere according as it condensed, and they have not ceased to belong to it inasmuch as by their motion, they have approached to the plane of this equator.

Let us now consider the zones of vapours, which have been successively abandoned. These zones ought, according to all probability, to form by their condensation, and by the mutual attraction of their particles, several concentrical rings of vapours circulating about the Sun. The mutual friction of the molecules of each ring ought to accelerate some and retard others, until they all had acquired the same angular motion. Consequently the real velocities of the molecules which are farther from the Sun, ought to be greatest. The following cause ought likewise to contribute to this difference of velocities: The most distant particles of the Sun, and which, by the effects of cooling and condensation, have collected so as to constitute the superior part of the ring, have always described areas proportional to the times, because the central force by which they are actuated has been constantly directed to this star; but this constancy of areas requires an increase of velocity, according as they approach more to each other. It appears that the same cause ought to diminish the velocity of the particles, which, situated near the ring, constitute its inferior part.

If all the particles of a ring of vapours continued to condense without separating, they would at length constitute a solid or a liquid ring. But the regularity which this formation requires in all the parts of the ring, and in their cooling, ought to make this phenomenon very rare. Thus the solar system presents but one example of it; that of the rings of Saturn. Almost always each ring of vapours ought to be divided into several masses, which, being moved with velocities which differ little from each other, should continue to revolve at the same distance about the Sun. These masses should assume a spheroidical form, with a rotatory motion in the direction of that of their revolution, because their inferior particles have a less real velocity than the superior; they have therefore constituted so many planets in a state of vapour. But if one of them was sufficiently powerful, to unite successively by its attraction, all the others about its centre, the ring of vapours would be changed into one sole spheroidical mass, circulating about the Sun, with a motion of rotation in the same direction with that of revolution. This last case has been the most common; however, the solar system presents to us the first case, in the four small planets which revolve between Mars and Jupiter, at least unless we suppose with Olbers, that they originally formed one planet only, which was divided by an explosion into several parts, and actuated by different velocities. Now if we trace the changes which a further cooling ought to produce in the planets formed of vapours, and of which we have suggested the formation, we shall see to arise in the centre of each of them, a nucleus increasing continually, by the condensation of the atmosphere which environs it. In this state, the planet resembles the Sun in the nebulous state, in which we have first supposed it to be; the cooling should therefore produce at the different limits of its atmosphere, phenomena similar to those which have been described, namely, rings and satellites circulating about its centre in the direction of its motion of rotation, and revolving in the same direction on their axes. The regular distribution of the mass of rings of Saturn about its centre and in the plane of its equator, results naturally from this hypothesis, and, without it, is inexplicable. Those rings appear to me to be existing proofs of the primitive extension of the atmosphere of Saturn, and of its successive condensations. Thus, the singular phenomena of the small eccentricities of the orbits of the planets and satellites, of the small inclination of these orbits to the solar equator, and of the identity in the direction of the motions of rotation and revolution of all those bodies with that of the rotation of the Sun, follow the hypothesis which has been suggested, and render it extremely probable. If the solar system was formed with perfect regularity, the orbits of the bodies which compose it would be circles, of which the planes, as well as those of the various equators and rings, would coincide with the plane of the solar equator. But we may suppose that the innumerable varieties which must necessarily exist in the temperature and density of different parts of these great masses, ought to produce the eccentricities of their orbits, and the deviations of their motions, from the plane of this equator.

In the preceding hypothesis, the comets do not belong to the solar system. If they be considered, as we have done, as small nebulæ, wandering from one solar system to another, and formed by the condensation of the nebulous matter, which is diffused so profusely throughout the universe, we may conceive that when they arrive in that part of space where the attraction of the Sun predominates, it should force them to describe elliptic or hyperbolic orbits. But as their velocities are equally possible in every direction, they must move indifferently in all directions, and at every posisble inclination to the elliptic; which is conformable to observation. Thus the condensation of the nebulous matter, which explains the motions of rotation and revolution of the planets and satellites in the same direction, and in orbits very little inclined to each other, likewise explains why the motions of the comets deviate from this general law.

The great eccentricity of the orbits of the comets, is also a result of our hypothesis. If those orbits are elliptic, they are very elongated, since their greater axes are at least equal to the radius of the sphere of activity of the Sun. But these orbits may be hyperbolic; and if the axes of these hyperbolæ are not very great with respect to the mean distance of the Sun from the Earth, the motion of the comets which describe them will appear to be sensibly hyperbolic. However, with respect to the hundred comets, of which the elements are known, not one appears to move in a hyperbola; hence the chances which assign a sensible hyperbola, are extremely rare relatively to the contrary chances. The comets are so small, that they only become sensible when their perihelion distance is inconsiderable. Hitherto this distance has not surpassed twice the diameter of the Earth's orbit, and most frequently, it has been less than the radius of this orbit. We may conceive, that in order to approach so near to the Sun, their velocity at the moment of their ingress within its sphere of activity, must have an intensity and direction confined within very narrow limits. If we determine by the analysis of probabilities, the ratio of the chances which in these limits, assign a sensible hyperbola to the chances which assign an orbit, which may without sensible error be confounded with a parabola, it will be found that there is at least six thousand to unity that a nebula which penetrates within the sphere of the Sun's activity so as to be observed, will either describe a very elongated ellipse, or an hyperbola, which, in consequence of the magnitude of its axis will be as to sense confounded with a parabola in the part of its orbit which is observed. It is not therefore surprising that hitherto no hyperbolic motions have been recognized.

The attraction of the planets, and perhaps also the resistance of the ethereal media, ought to change several cometary orbits into ellipses, of which the greater axes are much less than the radius of the sphere of the solar activity. It is probable that such a change was produced in the orbit of the comet of 1759, the greater axis of which was not more than thirty-five times the distance of the Sun from the Earth. A still greater change was produced in the orbits of the comets of 1770 and of 1805.

If in the zones abandoned by the atmosphere of the Sun, there are any molecules too volatile to be united to each other, or to the planets, they ought in their circulation about this star to exhibit all the appearances of the zodiacal light, without opposing any sensible resistance to the different bodies of the planetary system, both on account of their great rarity and also because their motion is very nearly the same as that of the planets which they meet.

An attentive examination of all the circumstances of this system renders our hypothesis still more probable. The primitive fluidity of the planets is clearly indicated by the compression of their figure, conformably to the laws of the mutual attraction of their molecules; it is moreover demonstrated by the regular diminution of gravity, as we proceed from the equator to the poles. This state of primitive fluidity to which we are conducted by astronomical phenomena, is also apparent from those which natural history points out. But in order fully to estimate them, we should take into account the immense variety of combinations formed by all the terrestrial substances which were mixed together in a state of vapour, when the depression of their temperature enabled their elements to unite; it is necessary likewise to consider the wonderful changes which this depression ought to cause in the interior and at the surface of the earth, in all its productions, in the constitution and pressure of the atmosphere, in the ocean, and in all substances which it held in a state of solution. Finally, we should take into account the sudden changes, such as great volcanic eruptions, which must at different epochs have deranged the regularity of these changes. Geology, thus studied under the point of view which connects it with astronomy, may, with respect to several objects, acquire both precision and certainty.

One of the most remarkable phenomena of the solar system is the rigorous equality which is observed to subsist between the angular motions of rotation and revolution of each satellite. It is infinity to unity that this is not the effect of hazard. The theory of universal gravitation makes infinity to disappear from this improbability, by shewing that it is sufficient for the existence of this phenomenon, that at the commencement these motions did not differ much. Then, the attraction of the planet would establish between them a perfect equality; but at the same time it has given rise to a periodic oscillation in the axis of the satellite directed to the planet, of which oscillation the extent depends on the primitive difference between these motions. As the observations of Mayer on the libration of the Moon, and those which Bouvard and

Nicollet made for the same purpose, at my request, did not enable us to recognize this oscillation; the difference on which it depends must be extremely small, which indicates with every appearance of probability the existence of a particular cause, which, has confined this difference within very narrow limits, in which the attraction of the planet might establish between the mean motions of rotation and revolution a rigid equality, which at length terminated by annihilating the oscillation which arose from this equality. Both these effects result from our hypothesis; for we may conceive that the Moon, in a state of vapour, assumed in consequence of the powerful attraction of the earth the form of an elongated spheroid, of which the greater axis would be constantly directed towards this planet, from the facility with which the vapours yield to the slightest force impressed upon them. The terrestrial attraction continuing to act in the same manner, while the Moon is in a state of fluidity, ought at length, by making the two motions of this satellite to approach each other, to cause their difference to fall within the limits, at which their rigorous equality commences to establish itself. Then this attraction should annihilate, by little and little, the oscillation which this equality produced on the greater axis of the spheroid directed towards the earth. It is in this manner that the fluids which cover this planet, have destroyed by their friction and resistance the primitive oscillations of its axis of rotation, which is only now subject to the nutation resulting from the actions of the Sun and Moon. It is easy to be assured that the equality of the motions of rotation and revolution of the satellites ought to oppose the formation of rings and secondary satellites, by the atmospheres of these bodies. Consequently observation has not hitherto indicated the existence of any such. The motions of the three first satellites of Jupiter present a phenomenon still more extraordinary than the preceding; which consists in this, that the mean longitude of the first, minus three times that of the second, plus twice that of the third, is constantly equal to two right angles. There is the ratio of infinity to one, that this equality is not the effect of chance. But we have seen, that in order to produce it, it is sufficient, if at the commencement, the mean motions of these three bodies approached very near to the relation which renders the mean motion of the first, minus three times that of the second, plus twice that of the third, equal to nothing. Then their mutual attraction rendered this ratio rigorously exact, and it has moreover made the mean longitude of the first minus three times that of the second, plus twice that of the third, equal to a semicircumference. At the same time, it gave rise to a periodic inequality, which depends on the small quantity, by which the mean motions originally deviated from the relation which we have just announced. Notwithstanding all the care Delambre took in his observations, he could not recognize this inequality, which, while it evinces its extreme smallness, also indicates, with a high degree of probability, the existence of a cause which makes it to disappear. In our hypothesis, the satellites of Jupiter, immediately after their formation, did not move in a perfect vacuo; the less condensible molecules of the primitive atmospheres of the Sun and planet would then constitute a rare medium, the resistance of which being different for each of the stars, might make the mean motions to approach by degrees to the ratio in question; and when these movements had thus attained the conditions requisite, in order that the mutual attraction of the three satellites might render this relation accurately true, it perpetually diminished the inequality which this relation originated, and eventually rendered it insensible. We cannot better illustrate these effects than by comparing them to the motion of a pendulum, which, actuated by a great velocity, moves in a medium, the resistance of which is inconsiderable. It will first describe a great number of circumstances; but at length its motion of circulation perpetually decreasing, it will be converted into an oscillatory motion, which itself diminishing more and more, by the resistance of the medium, will eventually be totally destroyed, and then the pendulum, having attained a state of repose, will remain at rest for ever.

VOLTA

Alessandro Volta was born at Como, Italy, February 18, 1745. In 1774 he became teacher of physics at Como and in 1749 professor at Pavia. He early took an interest in electricity. About 1790 Galvani discovered that the muscles of a frog contracted under the influence of electricity. Galvani thought the frog's muscles to act as a Leyden jar, Volta considered them rather a delicate electrometer. His experiments to confirm this theory led him to the discovery of the voltaic pile, which produced the first constant current of electricity and had an enormous influence on the science. Volta died in 1827.

NEW GALVANIC INSTRUMENT

On the Electricity Excited by the Mere Contact of Conducting Substances of Different Kinds. By Mr. Alex Volta, F. R. S., Prof. of Nat Philos. in the University of Pavia.

The chief of these results, and which comprehends nearly all the others, is the construction of an apparatus which resembles in its effects, viz. (such as giving shocks to the arms, &c.,) the Leyden phial, and still better, electric batteries weakly charged; acting continually, or whose charge, after each explosion, recharges itself again; which in short becomes perpetual, from one infallible charge, from one action or impulse on the electric fluid; but which besides differs essentially from the other, by this continual action which is proper to it, and because that instead of consisting, like the ordinary phials and electric batteries, in one or more isolated plates, or thin layers of those bodies deemed the only electrics, and armed with conductors or bodies called non-electrics, this new apparatus is formed only of a number of these last bodies, chosen even among the best conductors, and so the farthest removed, according to the usual opinion, from the electric principle. This astonishing apparatus is nothing but an assemblage of a number of good conductors of a different kind, arranged in a certain manner. Thus, 30, 40, 60, or more pieces of copper, or better of silver, each applied to a piece of tin, or still better of zinc, and an equal number of layers of water, or of some other liquid which may be a better conductor than simple water, as salt water, lye, &c., or of bits of card or leather, &c., soaked in such liquids. Of such layers interposed between each couple or combination of two different metals, one such alternate series, and always in the same order, of these three kinds of conductors, is all that constitutes M. Volta's new instrument; which imitates so well the effects of the Leyden phial or electric batteries; not indeed with the force and explosions of these, when highly charged; but only equalling the effects of a battery charged to a very weak degree, of a battery, however, having an immense capacity, but which besides infinitely surpasses the virtue and the power of these same batteries; as it has no need, like them, of being charged beforehand, by means of a foreign electricity; and as it is capable of giving the usual commotion as often as ever it is properly touched. This apparatus, as it resembles more the natural electric organ of the torpedo, or of the electric eel than the Leyden phial and the ordinary electric batteries, M. Volta calls the artificial electric organ. For the construction of this instrument, M. Volta provides some dozens of small, round metal plates of copper, or tin, or best of silver, about an inch in diameter, like shillings or half-crowns, and an equal number of plates of tin, or much better of zinc, of the same shape and size. These pieces he places exactly one upon another, forming a column, pillar or pile. He provides also as many round pieces of card, or leather, or such like spongy matter, capable of imbibing and retaining much of the water, or other liquid, when soaked in it. These soaked roullets or circles are to be a little less in diameter than the small metal discs or plates, that they may not jut out beyond them. All these discs are then placed horizontally on a table, one over another continually alternating, in a pile as high as will well support itself without tottering and falling down: beginning with a plate of either of the metals, as for instance, the silver, then upon that one of zinc, over which is to be put the soaked card; then other three discs, over these in the same order, viz. a silver, next a zinc, and then another moistened card, &c.

After having raised the pile to about 20 of these stages or triads of plates, it will be already capable, not only of affecting Cavallo's electrometer, assisted by the condenser, so as to raise it 10 or 15°, charging it by a simple touching, so as to cause it to give a spark, &c., as also to strike the fingers with which we touch the top or bottom of the column, with several small snaps, the fingers being wetted with water. But if to the 20 sets of triplets of the plates be added 20 or 30 more, disposed in the same order, the actions of the extended pile will be much stronger, and be felt through the arms up to the shoulders; and by continuing the touchings, the pains in the hands become insupportable.

M. Volta constructs and combines his apparatus in various ways and forms, more or less powerful, convenient or amusing. One is as follows (Fig. 1, pl. 13,), which he calls a *couronne de tasses*. He disposes in a row a number of cups of wood, or earth, or glass, or any thing but metal, half filled with pure water, or salt water or lye; these are all made to communicate in a kind of chain, by several metallic arcs of which one arm or link, Aa, or only the extremity A, immersed in one of the cups, is of copper, or of copper silvered, and the other Z, immersed in the following cup, is of tin, or rather of zinc, the other two being soldered together near the crown of the arch. It is evident that a series of these cups, thus connected together, either in a straight or curvd line, by the two metals and the intermediate liquid, is similar to the pillar or pile before described, and consequently will exhibit similar effects. Thus, to produce commotion or sensation in the hands and arms, we need only dip one hand into one of the cups and the finger of the other hand into another cup, sufficiently far from the former; and the action will be so much the stronger as the two cups are farther asunder, or have the more intermediate cups; and consequently the greatest by touching the first and the last in the chain.

As to the structure in the other method, by the column or pile, Mr. Volta found out various ways to prolong and extend it, in multiplying the metal plates without shaking it down; to render this instrument convenient, portable and durable; and among others, the three methods exhibited on figs. 2, 3, 4, pl. 13. In fig. 2, mmmm, are upright bars or rods, to the number of three or four, or more, erected from the bottom of the pile, and extended to a convenient height, inclosing the pile like a cage, to prevent its falling. These rods may be either of glass, wood or metal; only, in this last case, they must be hindered from touching the metal plates; which may be done either by covering each metal rod with a glass tube or by interposing between them and the pile some bands of cere-cloth or oiled paper or simple paper, or any imperfect conducting substance.

But the best expedient for forming the instrument of a great number of plates, as of 60, 80, or 1,000, is to divide the pile into two or more, as in the figures 3 and 4, where the pieces have all their respective positions or communications, as if it was one pile only, plied and turned. In all these figures the different metal plates are denoted by the letters A and Z, the initials of argent and zinc, and of the wet discs of card, or leather, &c., interposed at each pair of those metals, by a layer or band shaded black. The dotted lines show the contact of each couple of metal plates, A and Z, where they may be conveniently soldered together, cc, cc, cc, are metal plates forming the communication between one column, or section of a column, and another; and b, b, b, b, b, are basins of water, in communication with the bottoms or extremities of the piles.

M. Volta concludes with various remarks and cautions in using this instrument; showing that it is perpetual in its virtue, renewing its charge spontaneously, and serving most of the purposes of the ordinary electrical machines, and even affecting and manifesting its power by most of the human senses, viz. feeling, tasting, hearing, and seeing.

RELIGIOUS MOVEMENTS

JOHN WESLEY

John Wesley was born June 17 (June 28 by old style), 1703, at Epworth. He entered Oxford in 1720, and in 1726 became a fellow of Lincoln. In 1729, after an absence of two years, he returned to Oxford and began to take in pupils. Just before his return his brother Charles had induced a few students to meet him for weekly communion, and with the coming of John, the characteristics of the society became quite pronounced, for the members, besides taking weekly communion, began studying the Greek Testament together, observing regular fasting and private devotion, and visiting prisoners and the sick. It was during this period that they were given such sobriquets as "the Godly" and "Methodists," and the society at first fell off in numbers because of the criticism it had aroused.

In 1736 Wesley went to Georgia as a missionary. About this time he came somewhat under the influence of the Moravians, and had already accepted the doctrine of salvation by faith. Soon after his return to England in 1738, he felt that he had undergone his first real conversion, had actually been born in the "new birth." This doctrine of an actual conscious conversion through faith he commenced to preach as an evangelist along with his brother and Whitefield.

The Episcopal clergy began to discourage the new movement, so the evangelists began addressing the crowds in the open fields. In 1739 the societies first joined under the direct charge of Wesley, although all this time and until after Wesley's death Methodism considered itself only a society within the Episcopal church.

In 1740 the churches mostly refused the sacrament to the members of the society and the Wesleys administered it themselves. In 1741, lay preachers were called out to help them, and the next year leaders of the classes were appointed. The whole organization was under the entire charge of Wesley and continued so until his death. The first conference was held in 1744, and the powers of that body gradually increased until after Wesley's death it was ready to assume the control of the church.

In 1784 the American societies were organized as a church, independent of the Episcopalians and of English Methodism.

Wesley died in 1791. We give below his most important beliefs.

THE EARLY METHODISTS

The following queries concerning the Methodists were sent, I apprehend, from Holland or Germany to some person in England. The answer to each is in Mr. Wesley's handwriting; and the date prefixed is 1741. But if this be the true date, I conjecture, from the answer to the fourth and fifth query, that it must have been very early in this year, before Mr. Wesley and Mr. Whitefield separated on the doctrine of predestination. However, not being able to ascertain the date exactly, I have referred them to this place.

Quest. 1. Whether the number of Methodists is considerable, among the students and learned men?

Ans. "The number of Methodists is not considerable, among the students and learned men."

2. Whether at Oxford, where the Methodists first sprung up, there be still many of them among the scholars?

"There are very few of them now left, among the scholars at Oxford."

3. Whether they are all of one mind, and whether they have the same principles? Especially, 4. Whether those Methodists that are still at Oxford, approve of the sentiments and actions of Mr. Whitefield and Messrs. Wesleys?

"They are all of the same principles with the Church of England as laid down in her Articles and Homilies; and, 4. Do accordingly approve of the sentiments of Mr. Whitefield and Mr. Wesley, and of their publishing them elsewhere, since they have been shut out of the churches."

5. How they came to revive those doctrines, hitherto neglected by the clergy of the Church of England, of predestination, the new birth, and justification by faith alone? And 6. Whether they have the same from the Moravian brethren?

"Predestination is not a doctrine taught by the Methodists. But they do teach that men must be born again, and that we are saved through faith: and 6. "The latter of these they learned from some of the Moravian brethren; the former by reading the New Testament."

7. Whether they be orthodox in other doctrinal points; and whether they lead an unblameable Christian life.

"They openly challenge all that hear them to answer those questions, 'Which of you convinceth me of sin?' Or, of teaching any doctrine contrary to the Scripture? And the general accusation against them is, that they are righteous overmuch."

8. Whether they strictly regulate themselves according to the rule and discipline of the Moravian brethren; except that they still keep and observe the outward worship according to the Church of England?

"They do not regulate themselves according to the discipline of the Moravians, but of the English church."

9. Whether they do any real good among the common people?

"Very many of the common people, among whom they preach, were profane swearers, and now fear an oath; were gluttons, or drunkards, and are now temperate; were whoremongers, and are now chaste; were servants of the devil, and are now servants of God."

10. Why the bishops do not effectually inhibit them, and hinder their field and street preaching?

"The bishops do not inhibit their field and street preaching; 1. Because there is no law in England against it; 2. Because God does not yet suffer them to do it without law."

11. Whether the Archbishop of Canterbury is satisfied with them; as we are told?

"The Archbishop of Canterbury is not satisfied with them; especially since Mr. Molther, in the name of the Moravian church, told his Grace their disapprobation of them; and in particular of their field preaching."

12. Whether their private assemblies or societies are orderly and edifying?

"Their private assemblies and societies are orderly, and many say they find them edifying."

13. What opinion the Presbyterians, and particularly Dr. Watts, has of them?

"Most of the Presbyterians, and most all other denominations, are of the opinion, much religion hath made them mad."

14. Whether there are any Methodists among the Episcopal clergy of the Church of England?

"Mr. Whitefield, Hutchins, Robson, and the Messrs. Wesleys, and several others, are priests of the Episcopal Church of England."—Whitehead's "John and Charles Wesley."

GENERAL RULES OF THE SOCIETY

On the 19th Wesley reached Newcastle; and here and in the neighboring towns and villages he spent near six weeks in preaching and exhorting in praying and conversing with the people, and in regulating the societies. A great number of these societies were already formed exactly on the same principles, in various parts of the kingdom, though at a considerable distance one from another. But hitherto no general rules had been made to govern the whole. The two brothers, therefore, now drew up a set of rules which should be observed by the members of all their societies, and, as it were, unite them all into one body; so that a member at Newcastle knew the rules of the society in London, as well as at the place where he resided. They were printed under the title of "The Nature, Design, and General Rules of the United Societies, in London, Bristol, Newcastle-upon-Tyne," &c., and here it will be proper to insert them.

I. They state the nature and design of a Methodist society in the following words: "Such a society is no other than a company of men, having the form and seeking the power of godliness; united in order to pray together, to receive the word of exhortation, and to watch over one another in love, that they may help each other to work out their salvation.

"That it may the more easily be discerned whether they are indeed working out their own salvation, each society is divided into smaller companies, called classes, according to their respective places of abode. There are about twelve persons in every class, one of whom is styled the leader. It is his business: 1. To see each person in his class once a week at least, in order to inquire how their souls prosper. To advise, reprove, comfort or exhort, as occasions require; to receive what they are willing to give toward the relief of the poor. 2. To meet the minister and the stewards of the society once a week, in order to inform the minister of any that are sick; or of any that walk disorderly, and will not be reproved; to pay to the stewards what they have received of their several classes the week preceding; and to show their account of what each person has contributed.

II. "There is only one condition previously required in those who desire admission into these societies, a desire 'to flee from the wrath to come,' to be saved from their sins. But wherever this is really fixed in the soul, it will be shown by its fruits. It is therefore expected of all who continue therein that they should continue to evidence their desire of salvation.

1. "By doing no harm, by avoiding evil in every kind; especially that which is most generally practiced, such as

"The taking the name of God in vain; the profaning the day of the Lord, either by doing ordinary work thereon, or by buying or selling; drunkenness; buying or selling spirituous liquors, or drinking them, unless in cases of extreme necessity; fighting, quarreling, brawling; brother going to law with brother; returning evil for evil, or railing for railing; the using many words in buying or selling; the buying or selling uncustomed goods; the giving or taking things on usury; *i. e.*, unlawful interest; uncharitable or unprofitable conversation; particularly speaking evil of magistrates or ministers; doing to others as we would not they should do unto us; doing what we know is not for the glory of God: as

"The putting on gold, or costly apparel; the taking such diversions as cannot be used in the name of the Lord Jesus; the singing those songs, or reading those books, which do not tend to the knowledge or love of God; softness, or needless self-indulgence; laying up treasures upon earth; borrowing without a probability of paying; or taking up goods without a probability of paying for them.

"It is expected of all who continue in these societies, that they should continue to evidence their desire of salvation:

2. "By doing good, by being in every kind merciful after their power; as they have opportunity, doing good of every possible sort, as far as is possible to all men; to their bodies, of the ability which God giveth; by giving food to the hungry, by clothing the naked, by visiting

or helping them that are sick or in prison. To their souls, by instructing, reproving, or exhorting all they have intercourse with; trampling under foot that enthusiastic doctrine of devils, that 'we are not to do good unless our hearts be free to it.'

"By doing good especially to them that are of the household of faith, or groaning so to be; employing them preferably to others; buying one of another; helping each other in business; and so much the more, because the world will love its own, and them only.

"By all possible diligence and frugality, that the gospel be not blamed; by running with patience the race that is set before them, 'denying themselves and taking up their cross daily'; submitting to bear the reproach of Christ, to be as the filth and off-scouring of the world; and looking that men should 'say all manner of evil of them falsely for the Lord's sake.'

"It is expected of all who desire to continue in these societies, that they should continue to evidence their desire of salvation.

3. "By attending upon all the ordinances of God. Such are the public worship of God; the ministry of the word, either read or expounded; the supper of the Lord; family and private prayer; searching the Scriptures; and fasting and abstinence.

"These are the general rules of our societies; all of which we are taught of God to observe, even in His written word, the only rule, and the sufficient rule, both of our faith and practice. And all these we know His Spirit writes on every truly awakened heart. If there be any amongst us who observe them not, who habitually break any of them, let it be made known unto them who watch over that soul, as they that must give an account. We will admonish him of the error of his ways: we will bear with him for a season. But if he repent not, he hath no more place with us. We have delivered our own soul.

"John Wesley.
"Charles Wesley."

May 1, 1743.

THE DOCTRINE OF JUSTIFICATION

I. Q. 1. "What is it to be justified?

A. "To be pardoned and received into God's favor; into such a state, that if we continue therein, we shall be finally saved.

Q. 2. "Is faith the condition of justification?

A. "Yes; for every one who believeth not is condemned; and every one who believes is justified.

Q. 3. "But must not repentance and works meet for repentance go before this faith?

A. "Without doubt: if by repentance you mean conviction of sin; and by works meet for repentance, obeying God as far as we can, forgiving our brother, leaving off from evil, doing good and using His ordinances according to the power we have received.

Q. 4. "What is faith?

A. "Faith in general is a divine, supernatural *elenchos* of things not seen; *i. e.* of past, future, or spiritual things: it is a spiritual sight of God and the things of God.

"First, a sinner is convinced by the Holy Ghost, 'Christ loved me and gave Himself up for me.' This is that faith by which he is justified or pardoned, the moment he receives it. Immediately the same spirit bears witness, 'Thou art pardoned: thou hast redemption in His blood.' And this is saving faith, whereby the love of God is shed abroad in his heart.

Q. 5. "Have all Christians this faith? May not a man be justified and not know it?

A. "That all true Christians have such a faith as implies an assurance of God's love, appears from Rom. viii. 15.; Eph. iv. 32.; II. Cor. xiii. 5.; Heb. viii. 10; I. John iv. 10, v. 19. And that no man can be justified and not know it, appears further from the nature of the thing. For faith after repentance is ease after pain, rest after toil, light after darkness. It appears also from the immediate, as well as distant fruits thereof.

Q. 6. "But may not a man go to heaven without it?

A. "It does not appear from holy writ that a man who hears the gospel can (Mark xvi. 16): whatever a heathen may do. Rom. ii. 14.

Q. 7. "What are the immediate fruits of justifying faith?

A. "Peace, joy, love, power over all outward sin, and power to keep down inward sin.

Q. 8. "Does any one believe, who has not the witness in himself, or any longer than he sees, loves and obeys God?

A. "We apprehend not; seeing God being the very essence of faith; love and obedience the inseparable properties of it.

Q. 9. "What sins are consistent with justifying faith?

A. "No wilful sin. If a believer wilfully sins, he casts away his faith. Neither is it possible he should have justifying faith again, without previously repenting.

Q. 10. "Must every believer come into a state of doubt or fear, or darkness? Will he do so, unless by ignorance or unfaithfulness? Does God otherwise withdraw Himself?

A. "It is certain a believer need never again come into condemnation. It seems he need not come into a state of doubt or fear, or darkness: and that (ordinarily at least) he will not, unless by ignorance or unfaithfulness. Yet it is true that the first joy does seldom last long: that it is commonly followed by doubts and fears; and that God frequently permits great heaviness before any large manifestation of Himself.

Q. 11."Are works necessary to the continuance of faith?

A. "Without doubt; for a man may forfeit the free gift of God, either by sins of omission or commission.

Q. 12. "Can faith be lost, but for want of works?

A. "It cannot but through disobedience.

Q. 13. "How is faith made perfect by works?

A. "The more we exert our faith, the more it is increased. To him that hath shall be given.

Q. 14. "St. Paul says, Abraham was not justified by works. St. James, he was justified by works. Do they not contradict each other?

A. "No: 1. Because they do not speak of the same justification. St. Paul speaks of that justification which was when Abraham was seventy-five years old, above twenty years before Isaac was born. St. James of that justification which was when he offered up Isaac on the altar.

2. "Because they do not speak of the same works. St. Paul speaking of works that precede faith; St. James of works that spring from it.

Q. 15. "In what sense is Adam's sin imputed to all mankind?

A. "In Adam all die, *i. e.*, 1. Our bodies then became mortal. 2. Our souls died, *i. e.* were disunited from God. And hence, 3. We are all born with a sinful, devilish nature: by reason whereof, 4. We are children of wrath, liable to death eternal. Rom. v. 18.; Eph. ii. 3.

Q. 16. "In what sense is the righteousness of Christ imputed to all mankind, or to believers?

A. "We do not find it expressly affirmed in Scripture that God imputes the righteousness of Christ to any. Although we do find that faith is imputed to us for righteousness.

"That text, 'As by one man's disobedience all men were made sinners, so by the obedience of one, all were made righteous,' we conceive means, by the merits of Christ, all men are cleared from the guilt of Adam's actual sin.

"We conceive further, that through the obedience and death of Christ, 1. The bodies of all men become immortal after the resurrection. 2. Their souls receive a capacity of spiritual life; and, 3. An actual spark or seed thereof. 4. All believers become children of grace, reconciled to God, and 5, made partakers of the divine nature.

Q. 17. "Have we not then unawares leaned too much towards Calvinism?

A. "We are afraid we have.

Q. 18. "Have we not also leaned towards Antinomianism?

A. "We are afraid we have.

Q. 19. "What is Antinomianism?

A. "The doctrine which makes void the law through faith.

Q. 20. "What are the main pillars hereof?

A. 1. "That Christ abolished the moral law. 2. That therefore Christians are not obliged to observe it. 3. That one branch of Christian liberty, is liberty from obeying the commandments of God. 4. That it is bondage, to do a thing, because it is commanded, or forbear it because it is forbidden. 5. That a believer is not obliged to use the ordinances of God or to do good works. 6. That a preacher ought not to exhort to good works: not unbelievers, because it is hurtful; not believers, because it is needless.

Q. 21. "What was the occasion of St. Paul's writing his Epistle to the Galatians?

A. "The coming of certain men amongst the Galatians, who taught, Except ye be circumsised and keep the law of Moses ye cannot be saved.

Q. 22. "What is the main design therein?

A. "To prove, 1. That no man can be justified or saved by the works of the law, either moral or ritual. 2. That every believer is justified by faith in Christ without the works of the law.

Q. 23. "What does he mean by the works of the law. Gal. ii. 16, &c.

A. "All works which do not spring from faith in Christ.

Q. 24. "What by being under the law? Gal. iii. 23.

A. "Under the Mosaic dispensation.

Q. 25. "What law has Christ abolished?

A. "The ritual law of Moses.

Q. 26. "What is meant by liberty? Gal. v. 1.

A. "Liberty, 1. From the law; 2. From sin.

II. Q. 1. "How comes what is written on this subject to be so intricate and obscure? Is this obscurity from the nature of the thing itself? Or from the fault or weakness of those who have generally treated of it?

A. "We apprehend this obscurity does not arise from the nature of the subject, but partly from the extreme warmth of most writers who have treated of it.

Q. 2. "We affirm faith in Christ is the sole condition of justification. But does not repentance go before that faith? Yea, and (supposing there be opportunity for them) fruits or works meet for repentance?

A. "Without doubt they do.

Q. 3. "How then can we deny them to be conditions of justification? Is not this a mere strife of words?

A. "It seems not, though it has been grievously abused. But so the abuse cease, let the use remain.

Q. 4. "Shall we read over together Mr. Baxter's aphorisms concerning justification?

A. "By all means: which were accordingly read. And it was desired, that each person present would in the afternoon consult the Scriptures cited therein, and bring what objections might occur the next morning.

Q. 5. "Is an assurance of God's pardoning love absolutely necessary to our being in His favor? Or may there possibly be some exempt cases?

A. "We dare not positively say there are not.

Q. 6. "Is such an assurance absolutely necessary to inward and outward holiness?

A. "To inward, we apprehend it is; to outward holiness, we incline to think it is not.

Q. 7. "Is it indispensably necessary to final salvation?

A. "Love hopeth all things. We know not how far any may fall under the case of invincible ignorance.

Q. 8. "But what can we say of one of our own society, who dies without it, as J. W. at London?

A. "It may possibly be an exempt case (if the fact was really so). But we determine nothing. We leave his soul in the hands of Him that made it.

Q. 9. "Does a man believe any longer than he sees a reconciled God?

A. "We conceive not. But we allow there may be infinite degrees in seeing God: even as many as there are between him who sees the sun when it shines on his eyelids closed and him who stands with his eyes wide open, in the full blaze of his beams.

Q. 10. "Does a man believe any longer than he loves God?

A. "In no wise. For neither circumcision or uncircumcision avails, without faith working by love.

Q. 11. "Have we duly considered the case of Cornelius? Was he not in the favor of God, when his prayers and alms came up for a memorial before God? *i. e.,* before he believed in Christ?

A. "It does seem that he was, in some degree. But we speak not of those who have not heard the gospel.

Q. 12. "But were those works of his splendid sins?

A. "No; nor were they done without the grace of Christ.

Q. 13. "How then can we maintain that all works done before we have a sense of the pardoning love of God are sin? And, as such, an abomination to Him?

A. "The works of him who has heard the gospel and does not believe, are not done as God hath willed and commanded them to be done. And yet we know not how to say that they are an abomination to the Lord in him who feareth God, and from that principle does the best he can.

Q. 14. "Seeing there is so much difficulty in this subject, can we deal too tenderly with them that oppose us?

A. "We cannot; unless we were give up any part of the truth of God.

Q. 15. "Is a believer constrained to obey God?

A. "At first he often is. The love of Christ constraineth him. After this he may obey, or he may not; no constraint being laid upon him.

Q. 16. "Can faith be lost but through disobedience?

A. "It cannot. A believer first inwardly disobeys, inclines to sin with his heart; then his intercourse with God is cut off, *i. e.,* his faith is lost. And after this he may fall into outward sin, being now weak and like another man.

Q. 17. "How can such a one recover faith?

A. "By repenting and doing the first works. Rev. ii. 5.

Q. 18. "Whence is it that so great a majority of those who believe fall more or less into doubt or fear?

A. "Chiefly from their own ignorance or unfaithfulness: often from their not watching unto prayer; perhaps sometimes from some defect or want of the power of God in the preaching they hear.

Q. 19. "Is there not a defect in us? Do we preach as we did at first? Have we not changed our doctrines?

A. 1. "At first we preached almost wholly to unbelievers. To those therefore we spake almost continually of remission of sins through the death of Christ, and the nature of faith in His blood. And so we do still, among those who need to be taught the first elements of the gospel of Christ:

2. "But those in whom the foundation is already laid, we exhort to go on to perfection: which we did not see so clearly at first; although we occasionally spoke of it from the beginning.

3. "Yet we now preach, and that continually, faith in Christ as the prophet, priest and king, at least as clearly, as strongly and as fully as we did six years ago.

Q. 20. "Do not some of our assistants preach too much of the wrath, and too little of the love of God?

A. "We fear they have leaned to that extreme; and hence some of their hearers may have lost the joy of faith.

Q. 21. "Need we ever preach the terrors of the Lord to those who know they are accepted of Him?

A. "No; it is folly to do so; for love is to them the strongest of all motives.

Q. 22. "Do we ordinarily represent a justified state so great and happy as it is?

A. "Perhaps not. A believer walking in the light is inexpressibly great and happy.

Q. 23. "Should we not have a care of depreciating justification, in order to exalt the state of full sanctification?

A. "Undoubtedly we should beware of this: for one may insensibly slide into it.

Q. 24. "How shall we effectually avoid it?

A. "When we are going to speak of entire sanctification, let us first describe the blessings of a justified state as strongly as possible.

Q. 25. "Does not the truth of the gospel lie very near both to Calvinism and Antinomianism?

A. "Indeed it does: as it were, within a hair's breadth. So that it is altogether foolish and sinful, because we do not quite agree either with one or the other; to run from them as far as ever we can.

Q. 26. "Wherein may we come to the very edge of Calvinism?

A. 1. "In ascribing all good to the free grace of God; 2. In denying all natural free will and all power antecedent to grace; and 3. In excluding all merit from man; even for what he has or does by the grace of God.

Q. 27. "Wherein may we come to the edge of Antinomianism?

A. 1. "In exalting the merits and love of Christ. 2. In rejoicing evermore.

Q. 28. "Does faith supersede (set aside the necessity of) holiness or good works?

A. "In no wise. So far from it that it implies both, as a cause does its effects.

III. Q. 1. "Can an unbeliever (whatever he is in other respects) challenge anything of God's justice?

A. "Absolutely nothing but hell. And this is a point which we cannot too much insist on.

Q. 2. "Do we empty men of their own righteousness, as we did at first? Do we sufficiently labor when they begin to be convinced of sin, to take away all they lean upon? Should we not then endeavor with all our might to overturn their false foundations?

A. "This was at first one of our principal points. And it ought to be so still. For till all other foundations are overturned they cannot build upon Christ.

Q. 3. "Did we not then purposely throw them into convictions? Into strong sorrow and fear? Nay, did we not strive to make them inconsolable? Refusing to be comforted?

A. "We did. And so we should do still. For the stronger the conviction the speedier is the deliverance. And none so soon receive the peace of God as those who steadily refuse all other comfort.

Q. 4. "What is sincerity?

A. "Willingness to know and do the whole will of God. The lowest species thereof seems to be faithfulness in that which is little.

Q. 5. "Has God any regard to man's sincerity?

A. "So far, that no man in any state can possibly please God without it; neither indeed in any moment wherein he is not sincere.

Q. 6. "But can it be conceived that God has any regard to the sincerity of an unbeliever?

A. "Yes; so much that if he perseveres therein, God will infallibly give him faith.

Q. 7. "What regard may we conceive him to have to the sincerity of a believer?

A. "So much, that in every sincere believer he fulfills all the great and precious promises.

Q. 8. "Whom do you term a sincere believer?

A. "One that walks in the light, as God is in the light.

Q. 9. "Is sincerity the same with a single eye?

A. "Not altogether. The latter refers to our intention; the former to our will or desires.

Q. 10. "Is it not all in all?

A. "All will follow persevering sincerity. God gives everything with it; nothing without it.

Q. 11. "Are not sincerity and faith equivalent terms?

A. "By no means. It is at least as nearly related to works as it is to faith. For example: who is sincere before he believes? He that then does all he can: he that, according to the power he has received, brings forth 'fruits meet for repentance.' Who is sincere after he believes? He that, from a sense of God's love, is zealous of all good works.

Q. 12. "Is not sincerity what St. Paul terms a willing mind? II. Cor. viii. 12.

A. "Yes; if that word be taken in a general sense. For it is a constant disposition to use all the grace given.

Q. 13. "But do we not then set sincerity on a level with faith?

A. "No. For we allow a man may be sincere and not be justified, as he may be penitent and not be justified (not as yet), but he cannot have faith and not be justified. The very moment he believes he is justified.

Q. 14. "But do we not give up faith and put sincerity in its place, as the condition of our acceptance with God?

A. "We believe it is one condition of our acceptance, as repentance likewise is. And we believe it a condition of our continuing in a state of acceptance. Yet we do not put it in the place of faith. It is by faith the merits of Christ are applied to my soul. But if I am not sincere, they are not applied.

Q. 15. "Is not this that going about to establish your own righteousness, whereof St. Paul speaks, Rom. x. 4?

A. "St. Paul there manifestly speaks of unbelievers, who sought to be accepted for the sake of their own righteousness. We do not seek to be accepted for the sake of our sincerity; but through the merits of Christ alone. Indeed, so long as any man believes, he cannot go about (in St. Paul's sense) 'to establish his own righteousness.'

Q. 16. "But do you consider that we are under the covenant of grace? And that the covenant of works is now abolished?

A. "All mankind were under the covenant of grace from the very hour that the original promise was made. If by the covenant of works you mean that of unsinning obedience made with Adam before the fall; no man but Adam was ever under that covenant: for it was abolished before Cain was born. Yet it is not so abolished but that it will stand, in a measure, even to the end of the world, *i. e.,* if we do this, we shall live; if not, we shall die eternally; if we do well, we shall live with God in glory; if evil, we shall die the second death. For every man shall be judged in that day, and rewarded according to his works.

Q. 17. "What means then, 'to him that believeth, his faith is counted for righteousness?'

A. "That God forgives him that is unrighteous as soon as he believes, accepting His faith instead of perfect righteousness. But then observe, universal righteousness follows, though it did not precede faith.

Q. 18. "But is faith thus counted to us for righteousness, at whatsoever time we believe?

A. "Yes. In whatsoever moment we believe, all our past sins vanish away. They are as though they had never been, and we stand clear in the sight of God.

Q. 19. "Are not the assurance of faith, the inspiration of the Holy Ghost and the revelation of Christ in us, terms nearly of the same import?

A. "He that denies one of them must deny all; they are so closely connected together.

Q. 20. "Are they ordinarily, where the pure gospel is preached, essential to our acceptance?

A. "Undoubtedly they are; and as such, to be insisted on in the strongest terms.

Q. 21. "Is not the whole dispute of salvation by faith, or by works, a mere strife of words?

A. "In asserting salvation by faith we mean this: 1. That pardon (salvation begun) is received by faith, producing works. 2. That holiness (salvation continued) is faith working by love. 3. That heaven (salvation finished) is the reward of this faith.

"If you who assert salvation by works, or by faith and works, mean the same thing (understanding by faith the revelation of Christ in us, by salvation, pardon, holiness, glory,) we will not strive with you at all. If you do not, this is not a strife of words: but the very vitals, the essence of Christianity is the thing in question.

Q. 22. "Wherein does our doctrine now differ from that we preached while at Oxford?

A. "Chiefly in these two points: 1. We then knew nothing of that righteousness of faith, in justification; nor 2. Of the nature of faith itself as implying consciousness of pardon.

Q. 23. "May not some degree of the love of God go before a distinct sense of justification?

A. "We believe it may.

Q. 24. "Can any degree of sanctification or holiness?

A. "Many degrees of outward holiness may: yea, and some degrees of meekness, and several other tempers which would be branches of Christian holiness, but that they do not spring from Christian principles. For the abiding love of God cannot spring, but from faith in a pardoning God. And no true Christian holiness can exist without that love of God for its foundation.

Q. 25. "Is every man, as soon as he believes, a new creature, sanctified and pure in heart? Has he then a new heart? Does Christ dwell therein? And is he a temple of the Holy Ghost?

A. "All these things may be affirmed of every believer in a true sense. Let us not therefore contradict those who maintain it. Why should we contend about words?"

VOLTAIRE

Francois Marie Arouet de Voltaire was born at Paris November 21, 1694. His father was a prosperous notary, Francois Arouet, the suffix "de Voltaire" being added when the poet and philosopher left the Bastile. Voltaire's education was desultory until he was about ten years old, when he was sent to the Jesuit College Louis-le-Grand.

After he left school in 1711 he was constrained by his father to take up the reading of law, but he never entered into it in more than a half-hearted way, and gave most of his attention to literature.

His memberships in the coterie of the Duchess du Maine and certain lampoons ascribed to him against the regent Orleans cost him first exile and then eleven months in the Bastile. It was on leaving that he assumed the name by which he is commonly known. Soon afterwards he became deservedly famous by his drama, the "Œdipe," and his heroic poem, the "Henriade." This led him into close association with the nobility. A sharp reply to an insult from the Chevalier de Rohan occasioned his being beaten, and after being again confined in the Bastile, sent off to England.

This English visit had an immense effect on his views and writings. After his return to France he lived from 1734 to 1749 mostly with Madame du Chatelet at her country house Cirey, in the independent Duchy of Lorraine. All this time he was busy with his literary work. The next three years were spent with Frederick of Prussia, and were filled with quarrels characteristic both of Voltaire and Frederick. The last of his life was spent as a country gentleman, first near Geneva, then at Ferney. He died in 1778.

Voltaire was a great dramatist, but perhaps even a greater pamphleteer. His influence was constantly, but often secretly, lent against intoleration in religion and state. In those days he was considered a sceptic in religion and revolutionary in politics, but he was nevertheless a Deist, and it is doubtful if his revolutionary tendencies extended as far as merely the more liberal thought of today.

ON TOLERATION

WHETHER TOLERATION IS DANGEROUS; AND AMONG WHAT NATIONS IT IS PRACTICED

Some people will have it that, if we were to make use of humanity and indulgence towards our mistaken brethren who pray to God in bad French, it would be putting arms in to their hands, and we should see revived the bloody days of Jarnac, Moncontour, Coutras, Dreux, St. Denis &c. I know not how this may be, as I have not the gift of prophecy; but I really cannot discover the congruity of this reasoning, "that because these men took up arms against me when I oppressed them, they will do the same if I show them favour."

And here I would willingly take the liberty to entreat those who have the reins of government in hand, or are destined to fill the highest stations, for once to examine maturely, whether there is any reason to apprehend that indulgence would occasion the same rebellions as cruelty and oppression; and whether, what has happened under certain circumstances would happen under others of a different nature; or whether times, opinions and manners are always the same?

The Huguenots, it cannot be denied, have formerly been given into all the rage of enthusiasm, and have been polluted with blood as well as ourselves; but can it be said that the present generation is as barbarous as the former? Have not time and reason, that have lately made so great progress, together with good books, and that natural softness introduced from society, found their way among those who have the guidance of these people? And do we not clearly perceive that almost all Europe has undergone a change within the last century?

The hands of government have everywhere been strengthened, while the minds of the people have been softened and civilized; the general police, supported by numerous standing armies, leave us no longer any cause to fear the return of those times of anarchy, when Protestant boors and Catholic peasants were hastily called together from the labours of agriculture to wield the sword against each other's lives.

Alia tempora, aliae curae. It would be highly absurd in the present days to decimate the body of the Sorbonne because it formerly petitioned for the burning the *Pucelle d'Orleans*; because it declared Henry III. to have lost his right to the throne, and because it excommunicated and proscribed the illustrious Henry IV. We should not certainly think of prosecuting the other public bodies of the nation who committed the like excesses in those times of error and madness; it would not only be very unjust, but as ridiculous as if we were to oblige all inhabitants of Marseilles to undergo a course of physic, because they had the plague in 1720.

Should we at present go and sack Rome, as the troops of Charles the Fifth did, because Pope Sixtus the Fifth, in the year 1585, granted a nine years' indulgence to all Frenchmen who would take up arms against their sovereign? No, surely it is enough if we prevent the court of Rome from ever being guilty of such excesses for the future.

The rage inspired by a spirit of controversy, and the abuse made of the Christian religion from want of properly understanding it, has occasioned as much bloodshed, and produced as many calamities in Germany, England and even in Holland, as in France; and yet, at present the difference in religion occasions no disturbances in those countries; but the Jew, the Catholic, the Lutheran, the Calvinist, the Anabaptist, the Socinian, the Moravian, and a multitude of other sects, live in brotherly harmony together and contribute equally to the good of society.

In Holland they no longer fear that the disputations of a Gomar concerning predestination should bring the head of a grand pensionary to the block: nor in London, that the quarrels between the Presbyterians and the Episcopalians about a form of prayer and a surplice, should again spill the blood of their kings upon a scaffold. Ireland, now populous and rich, will not any more behold its Catholic inhabitants sacrificing, as an acceptable offering, the lives of their Protestant brethren, by burying them alive, hanging up mothers upon gibbets, and tying their daughters around their neck to see them expire together; ripping up women with child, taking the half-formed infants from the womb, and throwing them to swine or dogs to be devoured; putting a dagger into the hands of their manacled prisoners and forcing them to plunge it into the breasts of their fathers, their mothers, their wives or children, thereby hoping to make them guilty of parricide, and damn their souls while they destroyed their bodies: all of which we find related by Rapin, who served as an officer in the English service in Ireland, and who lived very near the time of those transactions, and confirmed by most of the English historians. No! such cruelties as they were never to be paralleled, so they doubtless will never be imitated. Philosophy, the sister of religion, has herself snatched the poignard from the hands of superstition, so long bathed in blood; and the human understanding, recovered from its delirium, stands amazed at the shocking brutalities into which it has been hurried by enthusiasm.

We ourselves know that in France there is a rich and populous province, where the Protestant religion prevails much more than that of the church of Rome. The University of Alsace consists almost entirely of Lutherans, and they are likewise in possession of most of the civil posts in that province; and yet the public peace has never once been disturbed by any quarrels about religion, since that province has belonged to our kings. And what is the reason? Because no one is persecuted there on account of their religion. Seek not to lay a restraint upon the mind, and you may always be sure that the mind will be yours.

I do not mean by this to insinuate that those who are of a different faith to the prince under whose government they live, should have an equal share in the places of profits and honour with those who are of the established religion of the state. In England the Roman Catholics, who are in general looked upon to be friends to the Pretender, are excluded from all civil employment and are even double taxed; but then in every other respect they enjoy the prerogatives of citizens.

Some of our bishops in France have been suspected of thinking that their honour and interest is concerned, in not suffering any Protestants within their diocese, and that this is the principal obstacle to allowing of toleration amongst us; but this I cannot believe. The Episcopal body in France is composed of persons of quality, who think and act in a manner suitable to their high birth; and as envy itself must confess that they are both generous and charitable, they therefore certainly cannot think that those whom they thus drive out of their diocese would become converts in any other country, but great honour would redound from the conversion of them at home; nor would the prelate be any loser by it in his temporals, seeing that the greater the number of the inhabitants, the greater is the value of the land.

A certain Polish bishop had a farmer, who was an Anabaptist, and a receiver of his rents who was a Socinian. Some person proposed to the bishop to prosecute the latter in the spiritual court for not believing in transubstantiation, and to turn the other out of his farm because he would not have his son christened till he was fifteen years of age; the prelate very prudently replied, that though he made no doubt of their being eternally damned in the next world, yet he found them extremely necessary to him in this.

Let us now for a while quit our own little sphere and take a survey of the rest of the globe. The grand seignior peaceably rules over subjects of twenty different religions; upwards of two hundred thousand Greeks live unmolested within the walls of Constantinople; the mufti himself nominates the Greek patriarch and presents him to the emperor; and at the same time allows of the residence of a Latin patriarch. The sultan appoints Latin bishops for some of the Greek isles; the form used on this occasion is as follows: "I command such a one to go and reside as bishop in the isle of Chios, according to the ancient custom and idle ceremonies of those people." The Ottoman empire swarms with Jacobines, Nestorians, Monothelites, Cophti, Christians of St. John, Guebres, and Banians; and the Turkish annals do not furnish us with one single instance of a rebellion occasioned by any of these different sects.

Go into Indian, Persia, and Tartary, and you will meet with the same toleration and the same tranquility. Peter the Great encouraged all kinds of religions throughout his vast empire: trade and agriculture have been gainers by it, and no injury ever happened therefrom to the body politic.

We do not find that the Chinese government, during the course of four thousand years that it has subsisted, has ever adopted any other religion than that of the Noachides, which consists in the simple worship of one God; and yet it tolerates the superstitions of Fo, and that of a multitude of bonzes; which might be productive of dangerous consequences did not the wisdom of the tribunals keep them within proper bounds.

It is true that the great Yong-T-Chin, the most wise and magnanimous of all the emperors of China, drove the Jesuits out of his kingdom; but this was not because that prince himself was non-tolerant, but on the contrary, because the Jesuits were so. They themselves, in their letters, have given us the speech the emperor made to them on that occasion: "I know, says he, that your religion admits not of toleration; I know how you have behaved in the Manilas and at Japan; you deceived my father, but think not to deceive me in the same manner." And if we read the whole of the conversation which he deigned to hold with them, we must confess him to be the wisest and most clement of all princes. How could he, indeed, with any consistency, keep in his kingdom European philosophers who, under the pretense of teaching the use of thermometers and œolypiles, had found means to debauch a prince of the blood? But what would this emperor have said, had he read our histories, and had he been acquainted with the times of the league and the gunpowder plot?

It was sufficient for him to be informed of the outrageous and indecent disputes between those Jesuits, Dominicans, Capuchins, and secular priests, who were sent as missionaries into his dominions from one extremity of the globe to preach up truth; instead of which, they employed their time in mutually pronouncing damnation against each other. The emperor, then, did no more than send away a set of foreigners, who were disturbers of the public peace. But with what infinite goodness did he dismiss them! and with what paternal care did he provide for their accommodation in their journey, and to prevent their meeting with any insult on their way! This very act of banishment might serve as an example of toleration and humanity.

The Japanese were the most tolerant of all nations; twelve different religions were peacefully established in their empire: when the Jesuits came, they made the thirteenth; and, in a very little time after their arrival, they would not suffer any other but their own. Every one knows the consequences of these proceedings: a civil war, as calamitous as that of the league, soon spread destruction and carnage through the empire; till at length the Christian religion was itself swallowed up in the torrents of blood it had set a flowing, and the Japanese for ever shut the entrance of their country against all foreigners, looking upon us as no better than savage beasts, such as those from which the English have happily cleared their island. Colbert, the minister, who knew the necessity we were in of the commodities of Japan, that wants nothing from us, laboured in vain to settle a trade with that empire; he found those people inflexible.

Thus then every thing on our Continent shows us, that we ought neither to preach up, nor to exercise non-toleration.

Let us now cast our eyes on the other hemisphere. Behold Carolina! whose laws were framed by the wise Locke; there every master of a family, who has only seven souls under his roof, may establish what religion he pleases, provided all those seven persons concur with him therein; and yet this great indulgence has not, hitherto, been the occasion of any disorders. God forbid, that I should mention this as an example to every master of a family to set up a particular worship in his house: I have only introduced it to show that the utmost lengths to which toleration can be carried, have never yet given rise even to the slightest dissensions.

And what shall we say of those pacific primitive Christians, who have, by way of derision, been called Quakers; and who, though some of their customs may perhaps be ridiculous, are yet remarkable for the virtue and sobriety of their lives, and for having in vain endeavoured to preach peace and good-will to the rest of mankind? There are at least an hundred thousand of them in Pennsylvania; discord and controversy are unknown in that happy spot where they have settled: the very name of their principal city, Philadelphia, is a continual memento to them, that all men are brethren, and is as once an example and reproach to those nations who have not yet adopted toleration.

To conclude, toleration has never yet excited civil wars; whereas its opposite has filled the earth with slaughter and desolation. Let any one then judge, which of the two is most entitled to our esteem, or which we should applaud, the mother who would deliver her son into the hand of the executioner, or she who would resign all right to him to save his life.

In all what I have said, I have had only the interest of nations in view and, as I pay all due respect to the doctrines of the church, I have in this article, only considered the physical and moral advantages of society. I therefore hope, that every impartial reader will properly weigh these truths, that he will view them in their proper light, and rectify what may be amiss. Those who read with attention, and reciprocally communicate their thoughts, will always have the start of the author.

In What Cases Toleration May be Admitted

Let me for once suppose, that a minister equally noble and discerning, that a prelate equally wise and humane, or a prince who is sensible that his interest consists in the increased number of his subjects, and his glory in their happiness, may deign to cast their eyes on this random and defective production. In this case, his own consummate knowledge will naturally lead him to ask himself, what hazard shall I run by seeing the land beautified and enriched by a greater number of industrious labourers, the aids augmented, and the state rendered more flourishing?

Germany, by this time, would have been a desert, covered with the unburied bodies of many different sects, slaughtered by each other, had not the peace of Westphalia happily procured a liberty of conscience.

We have Jews at Bordeaux, at Mentz, and in Alsace; we have Lutherans, Molinists, and Jansenists amongst us; can we not then admit protestants likewise under proper restrictions, nearly like those under which the Roman catholics are permitted in England? The greater the number of different sects, the less danger is to be apprehended from any one in particular; they become weaker in proportion as they are more numerous, and are easily kept in subjection by those just laws which prohibit riotous assemblies, mutual insults, and seditions, and which the legislative power will always properly support in their full vigour.

We know that there are several heads of families, who have acquired great fortunes in foreign countries, who would be glad to return to their native country. These require only the protection of the law of nature, to have their marriages to remain valid, and their children secured in the enjoyment of their present property, and the right of succeeding to the inheritance of their fathers, together with a protection for their persons. They ask no public places of worship; they aim not at the possession of civil employs, nor do they aspire to dignities either in church or state; for no Roman catholics can enjoy any of these, either in England or in any other protestant country. In this case, therefore, there is no occasion for granting great privileges, or delivering strongholds into the hands of a faction, but only to suffer a quiet set of people to breathe their native air; to soften the rigour of some edicts, which in former times might perhaps have been necessary, but at present are no longer so. It is not for us to direct the ministry what it has to do; it is sufficient, if we presume to plead the cause of an unfortunate and distressed people.

Many and easy are the methods to render these people useful to the state, and to prevent them from ever becoming dangerous: the wisdom of the legislature, supported by the military force, will certainly find out these methods, which other nations have employed with so much success.

It is certain, that there is still a number of enthusiasts among the lower kind of Calvinists; but, on the other hand, it is no less certain, that there is still a greater number among the lower kind of bigotted Roman catholics. The dregs of the madmen of St. Medard are passed over unnoticed in the nation, while the greatest pains is taken to exterminate the Calvinist prophets. The most certain means to lessen the number of the mad of both sorts, if any still remain, is to leave them entirely to the care of reason, which will infallibly enlighten the understanding in the long run, though she may be slow in her operations. Reason goes mildly to work, she persuades with humanity, she inspires mutual indulgence and forbearance; she stifles the voice of discord, establishes the rule of virtue and sobriety, and disposes those to pay a ready obedience to the laws, who might start from the hand of power when exerted to enforce them. Besides, are we to hold for nothing that contempt and ridicule which enthusiasm every where meets with in the present enlightened age, from persons of rank and education? This very contempt is the most powerful barrier that can be opposed to the extravagancies of all sectaries. Past times are as though they never had been. We should always direct our views from the point where we ourselves at present are, and from that to which other nations have attained.

There has been a time, in which it was thought a duty to issue edicts against all such who taught a doctrine contrary to the categories of Aristotle, or who opposed the abhorrence of a vacuum, quiddities, or the whole of the part of a thing. There are above an hundred volumes in Europe, containing the writings of civilians against magic, and the manner of distinguishing real sorcerers from pretended ones. The excommunication of grasshoppers and other insects hurtful to the fruits of the earth, was formerly much in use, and is still to be found in several rituals; that custom is now laid aside, and Aristotle, with his sorcerers and the grasshoppers, are left to themselves. Innumerable are the examples of these grave follies, which formerly were deemed of great importance; others have succeeded from time to time, but as soon as they have had their effect, and people begin to grow weary of them, they pass away and are no more heard of. If any one was, at present, to take it into his head to turn Eutichean, Nestorian, or Manichean, what would be the consequence? We should laugh at him in the same manner as at a person who should appear dressed after the ancient fashion, with a great ruff and slashed sleeves.

The first thing that opened the eyes of our nation was, when the Jesuits Le Tellier and Doucin drew up the bull Unigenitus, and sent it to the court of Rome, imagining they lived still in those times of ignorance, in which people adopted, without examination, the most absurd assertions. They even dared to proscribe a proposition, which is universally true in all cases and in all times, viz. "That the dread of an unjust excommunication ought not to hinder any one from doing his duty." This was, in fact, proscribing reason, the liberties of the Gallican church, and the very foundation of all morality; it was saying to mankind, "God commands you never to do your duty, when you are apprehensive of suffering any injustice. Never sure was so gross an insult offered to common sense, and yet this never occurred to these correspondents of the church of Rome. Nay, they even persuaded that court that this bull was necessary, that the nation desired it. Accordingly it was signed, sealed and sent back to France; and every one knows the consequences: assuredly, had they been foreseen, this bull would have been mitigated. Very warm disputes ensued upon it; but however, by the great prudence and goodness of the king, they were at length appeased.

It is much the same with regard to most of those points, in which the protestants and us at present differ; some of them are of little or no consequence, others again are more serious; but even in these latter, the rage of disputation is so far subsided, that the protestants now-a-days, no longer preach upon controversial points in any of their churches.

Let us then seize this period of disgust or satiety for such matters, or rather, indeed, of the prevalence of reason, as an epocha for restoring the public tranquility, of which it seems to be a pleasing earnest. Controversy, that epidemical malady, is now in its decline, and requires nothing more than a gentle regimen. In a word, it is the interest of the state, that these wandering sects, who have so long lived as aliens to their father's house, on their returning in a submissive and peaceable manner, should meet with a favourable reception; humanity seems to demand this, reason advises it, and good policy can have nothing to apprehend from it.

If Non-Toleration is Agreeable to the Law of Nature and of Society

The law of nature is that which nature points out to all mankind. You have brought up a child, that child owes you a respect as its parent, and gratitude as its benefactor. You have a right over the productions of the earth which you have raised by the labour of your own hands; you have given and received a promise, that promise ought to be kept.

The law of society can have no other foundation in any case than on the law of nature. "Do not that to another which thou wouldst not he should do unto thee," is the great and universal principle of both throughout the earth: now, agreeable to this principle, can one man say to another, "Believe that which I believe, and which thou thyself canst not believe, or thou shalt die?" And yet this is what is every day said in Portugal, in Spain, and at Goa. In some other countries indeed, they now content themselves with saying, "Believe as I do, or I will hold thee in abhorrence; believe like me, or I will do thee all the evil I can: wretch, thou art not of my religion, and therefore thou hast no religion at all, and oughtest to be held in execration by thy neighbours, thy city, and thy province."

If the law of society directs such a conduct, the Japanese ought then to hold the Chinese in detestation; the latter the Siamese, who should persecute the inhabitants of the Ganges; and they fall upon those of India; the Mogul should put to death the first Malabar he found in his kingdom; the Malabar should poignard the Persian; the Persian massacre the Turk; and, altogether, should fall upon us Christians, who have so many ages been cutting one another's throats.

The law of persecution then is equally absurd and barbarous; it is the law of tigers: nay, it is even still more savage for tigers destroy only for the sake of food, whereas we have butchered one another on account of a sentence or a paragraph.

Of Universal Toleration

It does not require any great art or studied elocution, to prove that Christians ought to tolerate each other. Nay, I shall go still farther, and say, that we ought to look upon all men as our brethren. How! call a Turk, a Jew, and a Siamese, my brother? Yes, doubtless; for are we not all children of the same parent, and the creatures of the same creator?

But these people hold us in contempt, and call us idolators! Well then, I should tell them that they were to blame. And I fancy that I could stagger the headstrong pride of an Imian, or a Talapoin, was I to address them in the following manner:

"This little globe, which is no more than a point, rolls together with many other globes, in that immensity of space in which we are all alike confounded. Man, who is an animal, about five feet high, is certainly a very inconsiderable part of the creation; but one of those hardly visible beings, says to others of the same kind inhabiting another spot of the globe, hearken to me, for the God of all these worlds has enlightened me: there are about nine hundred millions of us little insects who inhabit the earth, but my ant-hill is alone cherished by God, who holds all the rest in horror and detestation; those who live with me upon my spot will alone be happy, and all the rest eternally wretched."

They would here stop me short and ask, What madman could have made so ridiculous a speech? I should then be obliged to answer them, It is yourselves. After which I should endeavour to pacify them, but perhaps that would not be very easy.

I might next address myself to the Christians and venture to say, for example, to a Dominican, one of the judges of the inquisition, "Brother, you know that every province in Italy has a jargon of its own, and that they do not speak at Venice and Bergamo as they do at Florence. The academy de la Crusca has fixed the standard of the Italian language; its dictionary is an unerring rule, and Buon Matei's grammar is an infallible guide, from neither of which we ought to depart; but do you think that the president of the academy, or in his absence Buon Matei, could in conscience order the tongues of all the Venetians and Bergamese, who persisted in their own country dialect, to be cut out?"

The inquisitor would perhaps make me this reply: "There is a very wide difference; here the salvation of your soul is concerned; and it is entirely for your good that the directory of the inquisition ordains that you shall be seized, upon the deposition of a single person, though of the most infamous character; that you shall have no person to plead for you, nor even be acquainted with the name of your accuser; that the inquisitor shall promise you favour, and afterwards condemn you; that he shall make you undergo five different kinds of torture, and that at length you shall be either whipt, sent to the gallies, or burnt at the stake; father Ivouet, and the doctors Chaucalon, Zanchinus, Campegius, Royas, Felinus, Gomarus, Diarbarus, and Gemelinus are exactly of this opinion, consequently this pious practice will not admit of contradiction."

To all which I should take the liberty of making the following reply: "Dear brother, you may perhaps be in the right, and I am perfectly well convinced of the great benefit you intend me; but may I not be saved without all this?"

It is true that these horrible absurdities do not every day deform the face of the earth; but they have been very frequent, and one might easily collect instances enough to make a volume much larger than that of the holy gospels, which condemns such practices. It is not only very cruel to persecute in this short life, those who do not think in the same manner as we do, but I very much doubt if there is not an impious boldness in pronouncing them eternally damned. In my opinion, it little befits such insects of a summer's day, as we are, thus to anticipate the decrees of Providence. I am very far from opposing that maxim of the church, that "out of her pale there is no salvation:" on the contrary, I respect that and every other part of her doctrine; but, after all, can we be supposed to be intimately acquainted with the ways of God, or to fathom the whole depth of his mercy? Is it not permitted us to hope in him, as well as to fear him? Is it not sufficient if we are faithful sons of the church, without every individual presuming to wrest the power out of the hand of God, and determine, before Him, the future destiny of our fellow creatures?

When we wear mourning for a king of England, Denmark, Sweden, or Prussia, do we say that we are in mourning for a damned soul that is burning in hell? There are about forty millions of inhabitants in Europe who are not members of the church of Rome; should we say to every one of them, "Sir, as I look upon you to be infallibly damned, I shall neither eat, drink, converse, nor have any connections with you?"

Is there an ambassador of France, who when he is presented to the Grand Seignior for an audience, will seriously say to himself, his sublime highness will infallibly burn to all eternity, for having submitted to be circumcised? If he really thought that the Grand Seignior was a mortal enemy to God, and the object of divine vengeance, could he converse with such a person; nay indeed, ought he to be sent to him? But how could we carry on any commerce, or perform any of the civil duties of society, if we were convinced that we were conversing with persons destined to eternal damnation?

O ye different worshippers of a God of mercy! if ye have cruel hearts, if, while you adore that Deity who has placed the whole of his law in these few words, "Love God and your neighbour," you have loaded that pure and holy law with sophistical and unintelligible disputes, if you have lighted the flames of discord sometimes for a new word, and at others for a single letter only; if you have annexed eternal punishment to the omission of some few words, or of certain ceremonies, which other people cannot comprehend, I must say to you with tears of compassion for mankind: "Transport yourselves with me to that great instant in which all men are to receive judgment from the hand of God, who will then do unto every one according to their works, and with me behold all the dead of past ages appearing in his presence. Are you very sure that our heavenly father and creator will say to the wise and virtuous Confucius, to the great legislator Solon, to Pythagoras, Zaleucus, Socrates, Plato, the divine Antoninus, the good Trajan, to Titus the delight of human kind, and to many others who have been the models of human kind: Depart from me, wretches! into torments that know neither alleviation nor end; but are, like himself, everlasting. But you, my well beloved servants, John Chatel, Ravaillac, Cartouche, Damiens, &c. who have died according to the rules prescribed by the church, enter thou into the joy of your Lord, and sit forever at my right-hand in majesty and glory?"

Methinks I see you start with horror at these words; however, as they have escaped me, let them pass; I shall say nothing more to you.

An Address to the Deity

No longer then do I address myself to men, but to thee, God of all beings, of all worlds, and of all ages; if it may be permitted weak creatures, lost in immensity, and imperceptible to the rest of the universe, to presume to petition thee for aught, who hast given plenty of all things, and whose decrees are immutable as eternal. Deign to look with an eye of pity upon the errors annexed to our natures! let not these errors prove the sources of misery to us! Thou hast not given us hearts to hate, nor hands to kill each other; grant then that we may mutually aid and assist each other to support the burthen of this painful and transitory life! May the trifling differences in the garments that cover our frail bodies, in the mode of expressing our insignificant thoughts, in our ridiculous customs, and our imperfect laws, in our idle opinions, and in our several conditions and situations, that appear so disproportionate in our eyes, and all are equal in thine; in a word, may the slight variations that are found amongst the atoms called men, not be made use of by us as signals of mutual hatred and persecution! May those who worship thee by the light of tapers at noon-day, bear charitably with those who content themselves with the light of that glorious planet thou hast placed in the midst of the heavens! May those who dress themselves in a robe of white linen to teach their hearers that thou art to be loved and feared, not detest or revile those who teach the same doctrine in long cloaks of black wool! May it be accounted the same to adore thee in a dialect formed from an ancient or a modern language! May those, who, clothed in vestments of crimson or violet colour, rule over a little parcel of that heap of dirt called the world, and are possessed of a few round fragments of a certain metal, enjoy without pride or insolence what they call grandeur and riches, and may others look on them without envy; for thou knowest, O God, that there is nothing in all these vanities proper to inspire envy or pride.

May all men remember that they are brethren! may they alike abhor that tyranny which seeks to subject the freedom of the will, as they do the rapine which tears from the arms of industry the fruits of its peaceful labours! And if the scourge of war is not to be avoided, let us not mutually hate and destroy each other in the midst of peace; but rather make use of the few moments of our existence to join in praising, in a thousand different languages, from one extremity of the world to the other, thy goodness, O all merciful creator, to whom we are indebted for that existence.

EIGHTEENTH CENTURY POLITICAL ECONOMY

QUESNAY

In our introduction to the political economy of the seventeenth century earlier in this volume we trace, for the sake of historical unity, a sufficient introduction to the political economy of the eighteenth century also.

François Quesnay was born at Mérey, about twenty-eight miles from Paris, June 4, 1694. His father was an advocate, who sacrificed his business to his love for conciliating his neighbors. He learned something of the sciences, and some Greek and Latin without the aid of a school or tutor. It is said that many times he walked to Paris for a book. He studied medicine in Paris and in 1718 established a practice at Mantes, his clients numbering such great persons as the Maréchal de Noailles and the queen. In 1730 he was made secretary of an academy of surgery at Paris. Some fifteen years later he became physician to Louis XV.

From this time he seems to have been especially interested in economic studies. About 1750 he met M. de Gournay and the two men became the center of what has become known as the physiocrat school. The general idea of the school was to exalt the economic importance of nature rather than legislation. Along this line they believed the production of raw materials to be the only production of wealth, eulogized agriculture, and wished freedom in trade. One of their great representatives in politics was Turgot, whose reforms if carried out would have done much to alleviate the French Revolution.

Quesnay died in 1774.

GENERAL MAXIMS OF THE ECONOMICAL GOVERNMENT IN AN AGRICULTURAL KINGDOM

MAXIM I. UNITY OF AUTHORITY

Let the sovereign authority be unrivalled and superior to all individuals of society, and to all unjust enterprises of particular interests; for the domination and subjection of certain forces is the safeguard and lawful interest of all. The destructive theory of the system of counterforces in a government can show nothing but discord between the large proprietors and the lower class of farmers. The division of society into different orders of citizens of which some exercise sovereign authority over others, destroys the general interest of the nation itself and introduces the dissension of particular interests between the different classes of people: this division would invest the order of the government of an agricultural kingdom that would unite all interests, having as the capital object, the prosperity of agriculture, which in itself is the source of the state's and the people's riches.

II. Let the Nation be instructed as to General Natural Laws, which make a Government more Perfect.

The study of human jurisprudence does not suffice to make statesmen; it is necessary that they who are fitting themselves for public service be constrained to the observance of natural law, which tends toward the good of society as a whole. It is also necessary that the clear and practical knowledge a nation acquires by experience and reflection be added to the general science of government; in order that the sovereign authority, always surer in the light of experience, institutes the best laws for the well-being of all to reach and embrace the greatest possible prosperity for society.

III. Earth, Agriculture, Sole Source of Riches.

Let the sovereign and the nation never lose sight of the fact that *the earth is the sole source of all riches,* and that it is agriculture which multiplies riches.

For it is the augmentation of riches that assures the wealth of the population; men and wealth cause agriculture to prosper, extend commerce, animate industry, increase and perpetuate all wealth. Upon that abundant source of wealth, agriculture, depends the success of all the parties concerned in the administration of the kingdom.

IV. Let Landed Property and Movable Riches be assured to Those who are the Legitimate Possessors of Them.

For the security of property is the substructure upon which the economic order of society rests. Without the certainty of the security and safety of property the land would remain untilled. There would be neither proprietors nor tenants to make the necessary outlay in cultivating the land, if the title to the land and its products were not assured to them who made the necessary outlay towards improvement and cultivation. It is the surety of permanent possession that brings about the employ of labor and riches in the improvement and culture of the land, and in industrial and commercial enterprises. Nothing but a sovereign power can assure the property of subjects who have a primitive right to the portion of the fruits of the earth, the sole source of riches.

V. The Tax,—not to destroy.

Let taxes be not destructive nor disproportionate to the revenue of the nation; let increase in taxes attend increase in revenue; let taxes be immediately placed on the net product of property in land, and not on the wages of man, nor on produce, where it would multiply the cost of collection, would be prejudicial to commerce, and would annually destroy a portion of the wealth of the nation. Neither should taxes be placed on the riches of cultivators of landed property; for investment in the agriculture of a kingdom, *i. e.*, advance money expended in agriculture, must be regarded as a landed estate to be preciously preserved for the raising of taxes and revenue and subsistence for all classes of citizens. Otherwise the tax would degenerate to spoliation and promptly cause the state to ruin and decay.

VI. Sufficient Investment.

Let the investment of cultivators be sufficient to cause annually to re-appear from the expense undergone in cultivating the land the greatest possible amount of production: for if the investment is not sufficient the expense of culture is larger in proportion and gives less of net product.

VII. Complete Circulation.

Let the sum total of the revenues be annually returned into and along the entire course of circulation; let no money fortunes be accumulated, or rather, let there be compensation between those which are made and those which are derived in the circulation; for otherwise the money fortunes would arrest the distribution of a portion of the annual revenue of the nation and would withhold the moneys of the kingdom to the harm and prejudice of their re-investment into the cultivation of the land, from paying the artisan's wages, from making the various professions lucrative and would also diminish the reproduction of revenues and taxes.

VIII. Favor for Productive Expenditures.

Let the economic government favor productive expenditures and the commerce of the land's products and let fruitless expenditure attend to itself.

IX. Preference for Agriculture.

Let a nation which has a large territory to cultivate and the facilities to carry on a large commerce with the land's products not use too much of the people's money in the manufactures and in the commerce of luxuries to the prejudice of labor and agricultural investments; for above all, the kingdom would well be a people of rich agriculturists.

X. Revenue Expended in the Country.

Let none of the revenue pass into the home of the stranger without return either in money or merchandise.

XI. Evils of Emigration.

Let the desertion of those inhabitants who would take with them their wealth, to the loss of the kingdom, be prevented.

XII. Protection of the Person and the Wealth of Agriculturists.

Let the children of rich farmers establish themselves in the country so as to perpetuate and preserve husbandry; for if vexation of any kind causes them to abandon the country and determines them to repair into the cities they take with them the wealth of their fathers who were employed in agriculture. It is less men than wealth that should be drawn into the country, for the more one employs money in agriculture the less it occupies men and prospers more and gives more to the revenue. Take, for example, grain, the great product of the rich agriculturist, and compare that with the contracted tillage of a poor tenant who labors with an axe or a cow.

XIII. Freedom of Cultivation.

Let each one be free to cultivate in his own field those products that his interest, his faculties, and the nature of the earth suggest to him will produce the largest possible result. One ought not to favor monopoly in the cultivation of land, for it is prejudicial to the general revenue of the nation. The precedent that favors the abundance of products of the greatest need, in preference to other productions, disregarding the purchasable value of the one or the other, is inspired by that short-sightedness that sees not the effects of exterior reciprocal commerce that supplies to all; and which fixes the price of the products that each nation can cultivate with the greatest profit. Next to the riches of land cultivation, it is the revenue and taxes that are the riches most needed in a state to defend subjects against scarcity of food and want, against enemies, and to sustain the glory and strength of the monarch and the prosperity of the nation.

XIV. Multiplication of Cattle.

Let the raising and multiplication of cattle be favored; for it is they that furnish to the earth the manure that produces the richest harvests.

XV. Cultivation Extensive Enough.

Let the land employed in the culture of grain be reunited as far as possible to form large farms to be cultivated by rich laborers; for there is less of expense and much more of net products in the larger enterprises of agriculture than in the smaller. The multiplicity of small farmers is prejudicial to the population. A more secure population, more freedom for the different occupations, and different labors that divide men into different classes, it is this that is maintained by the net product. All thrift and economy profits the work that can be done by means of animals, machinery, rivers, etc., returns to the advantage of the people and the state, for the greater the net product, the more of gain is there to the people of whatever service or occupation.

XVI. No Obstacle to the Exportation of Goods.

External commerce of the products of the land should not be arrested nor prevented in any way, for it is the demand, the market, that regulates the production each year.

XVII. Freedom and Ease in Transportation.

Let the means of the transportation of the productions of manual labor be facilitated by repairing roadways, and by the navigation of canals, of rivers, and of the sea; for the more that is saved in the act of carrying on commerce, so much more is added to the revenue of the territory.

XVIII. Good Prices for Agricultural Products and Merchandise.

Let the price of agricultural products and merchandise, in a country, be not lowered; for then reciprocal commerce with foreign countries would become disadvantageous to the nation. As is the purchasable value of things, so is the revenue. Abundance and no value is not wealth. Dearth and high prices is misery. Abundance and high prices is opulence.

XIX. Low Prices Are Harmful to the People.

Low prices are not profitable to the laboring class; for cheapness of products lowers the wages of the laboring people, diminishes their comfort, procures less lucrative work and occupation for them, and destroys the revenue of the nation.

XX. Comfort for the Lowest Classes of Citizens.

Let the comfort of the lowest classes of citizens be not diminished; for they must aid in the consumption of products, if reproduction and the revenue of the nation are not to be lessened.

XXI. Avoid Unfruitful Economy.

Let the landlords and those who exercise the lucrative professions not give themselves up to unfruitful economy, for this would cut off from circulation and distribution a portion of their revenue or of their gains.

XXII. Little or None of the Luxury of Decoration.

Let the luxury of decoration not be entertained to the detriment of land culture, or any of the investments and outlays made necessary for subsistence, for the stability of these preserves good prices, the demand for the lands, products, and the production of the nation's revenue.

XXIII. Reciprocity in Commerce.

Let the nation not suffer from loss through reciprocal commerce with other countries even if this commerce were profitable to the merchants, who would gain, regardless of the welfare of fellow-citizens, in the sale of commodities thus brought about. The accumulations of the fortunes of these merchants would create a curtailment in the circulation of revenue prejudicial to distribution and reproduction.

XXIV. Balance of Money in Trade is Illusory.

Let no one be deceived by an apparent advantage in reciprocal commerce with foreign countries, which is simply a balance received in money, without examining and comparing the profits that result from the merchandise one has sold and the merchandise which has been bought. For often the loss is to that nation which receives a surplus in money. And that loss reacts to the prejudice of the distribution and reproduction of the revenues.

XXV. Complete Liberty in Commerce.

Let there be complete liberty in commerce; for the surest, most exact, and most profitable policy for interior and exterior commerce of the state and nation consists in the greatest possible freedom in competition.

XXVI. Attention to the Revenue Rather Than to Population.

Let there be less attention given to the augmentation of the population than to the accumulation of revenue, for greater freedom or ease in procuring large revenues is preferable to the greater pressing wants of subsistence, created by a population, and which exceed the revenue; and the resources are greater for the needs of a state when a people are in comfort, and there are also more means to make agriculture prosperous.

XXVII. No Economization of the Necessary Public Expenditures.

Let the government occupy itself with those operations necessary for the prosperity of the kingdom rather than with attention toward expenditures; for with greater riches the larger expenses will cease to appear so excessive. But one should not confound a perversion of funds with simple expenses, for such a perversion can dissipate all the riches of a nation and of the sovereign.

XXVIII. No Pecuniary Fortunes in the Administration of Taxes.

Let the administration of the finances be in the tax collection, not in the expenses of the government, nor occasion pecuniary fortunes that take away a portion of the revenue from circulation, distribution and reproduction.

XXIX. Credit of Financiers, Harmful Resource.

Let no one hope for resources, to meet the extraordinary needs of a state, but in the prosperity of the nation, and not in the credit of financiers; for pecuniary fortunes are clandestine riches that know not king nor country.

XXX. Borrowing Always Injurious.

Let the state avoid loans formed of the funds of financiers, for they burden a state with devouring debts, occasion a commerce or traffic of the finances, through the agency of negotiable paper, and where the rebate or discount augments more and more the unfruitful pecuniary fortunes. These fortunes separate money from agriculture and deprive the country of the necessary riches for the improvement of real estate and the exploitation of agriculture.

TRANSLATED BY E. R. BLAKE.

ADAM SMITH

Adam Smith was born June 5, 1723, in Fifeshire, Scotland, a few months after the death of his father. In 1737 he began attending the University of Glasgow, and in 1740 changed to Oxford. In 1748 he gave lectures on literature in Edinburgh, and about this time became a friend of David Hume. In 1751 he was made professor of logic at Glasgow and later professor of moral philosophy.

In 1763 he took charge of the young Duke of Buccleuch on his travels, and remained abroad for three years. For the next ten years he lived with his mother at Kirkcaldy, happy and contented, and busy with his *Wealth of Nations*. This was published in 1776.

In 1778 he was made a commissioner of customs at Edinburgh, and in 1787 Lord Rector of Glasgow University. He died in 1790.

The *Wealth of Nations* is in some respects a compromise between the mercantile and physiocrat theories, but its ideas are much further wrought out. Smith considered the nation but the sum of the individuals in it, and wealth to be due to both labor and natural resources. He buried the restrictive theory of trade for many years, but believed in such public interference as compulsory education, public fortifications and improvements and the like. He made a minute analysis of the factors of economics, such as the division of labor, exchange, value, price, wages, profits, rent, capital and wealth, taxes, etc., and placed the whole subject on a scientific basis.

The direct political outgrowth of his ideas was free trade in England and non-intervention in her colonies.

OF THE PRINCIPLE OF THE COMMERCIAL OR MERCANTILE SYSTEM

That wealth consists in money, or in gold and silver, is a popular notion which naturally arises from the double function of money, as the instrument of commerce, and as the measure of value. In consequence of its being the instrument of commerce, when we have money we can more readily obtain whatever else we have occasion for, than by means of any other commodity. The great affair, we always find, is to get money. When that is obtained, there is no difficulty in making any subsequent purchase. In consequence of its being the measure of value, we estimate that of all other commodities by the quantity of money which they will exchange for. We say of a rich man that he worth a great deal, and of a poor man that he is worth very little money. A frugal man, or a man eager to be rich, is said to love money; and a careless, a generous or a profuse man, is said to be indifferent about it. To grow rich is to get money; and wealth and money, in short, are in common language considered as in every respect synonymous.

A rich country, in the same manner as a rich man, is supposed to be a country abounding in money; and to heap up gold and silver in any country is supposed to be the readiest way to enrich it. For some time after the discovery of America, the first inquiry of the Spaniards, when they arrived upon any unknown coast, used to be, if there was any gold or silver to be found in the neighbourhood? By the information which they received, they judged whether it was worth while to make a settlement there, or if the country was worth the conquering. Plano Carpino, a monk sent ambassador from the king of France to one of the sons of the famous Gengis Khan, says that the Tartars used frequently to ask him if there were plenty of sheep and oxen in the kingdom of France. Their inquiry had the same object with that of the Spaniards. They wanted to know if the country was rich enough to be worth the conquering. Among the Tartars, as among all other nations of shepherds, who are generally ignorant of the use of money, cattle are the instruments of commerce and the measures of value. Wealth, therefore, according to them, consisted in cattle, as according to the Spaniards it consisted in gold and silver. Of the two, the Tartar notion perhaps was the nearest to the truth.

Mr. Locke remarks a distinction between money and other movable goods. All other movable goods, he says, are of so consumable a nature that the wealth which consists in them cannot be much depended on, and a nation which abounds in them one year may, without any exportation, but merely by their own waste and extravagance, be in great want of them the next. Money, on the contrary, is a steady friend, which, though it may travel about from hand to hand, yet if it can be kept from going out of the country, is not very liable to be wasted and consumed. Gold and silver, therefore, are, according to him, the most solid and substantial part of the movable wealth of a nation, and to multiply those metals ought, he thinks, upon that account, to be the great object of its political economy.

Others admit that if a nation could be separated from all the world, it would be of no consequence how much or how little money circulated in it. The consumable goods which were circulated by means of money, would only be exchanged for a greater or a smaller number of pieces; but the real wealth or poverty of a country, they allow, would depend altogether upon the abundance or scarcity of those consumable goods. But it is otherwise, they think, with countries which have connections with foreign nations, and which are obliged to carry on foreign wars, and to maintain fleets and armies in distant countries. This, they say, cannot be done but by sending abroad money to pay them with; and a nation cannot send much money abroad, unless it has a good deal at home. Every such nation, therefore, must endeavour in time of peace to accumulate gold and silver, that, when occasion requires, it may have wherewithal to carry on foreign wars.

In consequence of these popular notions, all the different nations of Europe have studied, though to little purpose, every possible means of accumulating gold and silver in their respective countries. Spain and Portugal, the proprietors of the principal mines which supply Europe with those metals, have either prohibited their exportation under the severest penalties, or subjected it to a considerable duty. The like prohibition seems anciently to have made a part of the policy of most other European nations. It is even to be found, where we should least of all expect to find it, in some old Scotch Acts of Parliament, which forbid under heavy penalties the carrying gold or silver forth of the kingdom. The like policy anciently took place both in France and England.

When those countries became commercial, the merchants found this prohibition, upon many occasions, extremely inconvenient. They could frequently buy more advantageously with gold and silver than with any other commodity, the foreign goods which they wanted, either to import into their own, or to carry to some other foreign country. They remonstrated, therefore, against this prohibition as hurtful to trade.

They represented, first, that the exportation of gold and silver in order to purchase foreign goods, did not always diminish the quantity of those metals in the kingdom. That, on the contrary, it might frequently increase that quantity; because, if the consumption of foreign goods was not thereby increased in the country, those goods might be re-exported to foreign countries, and being there sold for a large profit, might bring back much more treasure than was originally sent out to purchase them. Mr. Mun compares this operation of foreign trade to the seed-time and harvest of agriculture. "If we only behold," says he, "the actions of the husbandman in the seed-time, when he casteth away much good corn into the ground, we shall account him rather a madman than a husbandman. But when we consider his labours in the harvest, which is the end of his endeavours, we shall find the worth and plentiful increase of his actions."

They represented, secondly, that this prohibition could not hinder the exportation of gold and silver, which, on account of the smallness of their bulk in proportion to their value, could easily be smuggled abroad. That this exportation could only be prevented by a proper attention to what they called the balance of trade. That when the country exported to a greater value than it imported, a balance became due to it from foreign nations, which was necessarily paid to it in gold and silver, and thereby increased the quantity of those metals in the kingdom. But that when it imported to a greater value than it exported, a contrary balance became due to foreign nations, which was necessarily paid to them in the same manner, and thereby diminished that quantity. That in this case to prohibit the exportation of those metals could not prevent it, but only, by making it more dangerous, render it more expensive. That the exchange was thereby turned more against the country which owed the balance than it otherwise might have been; the merchant who purchased a bill upon a foreign country being obliged to pay the banker who sold it, not only for the natural risk, trouble, and expense of sending the money thither, but for the extraordinary risk arising from the prohibition. But that the more the exchange was against any country, the more the balance of trade became necessarily against it; the money of that country becoming necessarily of so much less value, in comparison with that of the country to which the balance was due. That if the exchange between England and Holland, for instance, was five per cent against England, it would require a hundred and five ounces of silver in England to purchase a bill for a hundred ounces of silver in Holland: that a hundred and five ounces of silver in England, therefore, would be worth only a hundred ounces of silver in Holland, and would purchase only a proportionable quantity of Dutch goods; but that a hundred ounces of silver in Holland, on the contrary, would be worth a hundred and five ounces in

England, and would purchase a proportionable quantity of English goods: that the English goods which were sold to Holland would be sold so much cheaper; and the Dutch goods which were sold to England, so much dearer, by the difference of the exchange; that the one would draw so much less Dutch money to England, and the other so much more English money to Holland, as this difference amounted to: and that the balance of trade, therefore, would necessarily be so much more against England, and would require a greater balance of gold and silver to be exported to Holland.

Those arguments were partly solid and partly sophistical. They were solid so far as they asserted that the exportation of gold and silver in trade might frequently be advantageous to the country. They were solid, too, in asserting that no prohibition could prevent their exportation, when private people found any advantage in exporting them. But they were sophistical in supposing that, either to preserve or to augment the quantity of those metals required more the attention of government, than to preserve or to augment the quantity of any other useful commodities, which the freedom of trade, without any such attention, never fails to supply in the proper quantity. They were sophistical, too, perhaps, in asserting that the high price of exchange necessarily increased what they called the unfavourable balance of trade, or occasioned the exportation of a greater quantity of gold and silver. That high price, indeed, was extremely disadvantageous to the merchants who had any money to pay in foreign countries. They paid so much dearer for the bills which their bankers granted them upon those countries. But though the risk arising from the prohibition might occasion some extraordinary expense to the bankers, it would not necessarily carry any more money out of the country. This expense would generally be all laid out in the country, in smuggling the money out of it, and could seldom occasion the exportation of a single sixpence beyond the precise sum drawn for. The high price of exchange, too, would naturally dispose the merchants to endeavour to make their exports nearly balance their imports, in order that they might have this high exchange to pay upon as small a sum as possible. The high price of exchange, besides, must necessarily have operated as a tax in raising the price of foreign goods, and thereby diminishing their consumption. It would tend, therefore, not to increase, but to diminish what they called the unfavourable balance of trade, and consequently the exportation of gold and silver.

Such as they were, however, those arguments convinced the people to whom they were addressed. They were addressed by merchants to parliaments, and to the councils of princes, to nobles and to country gentlemen; by those who were supposed to understand trade, to those who were conscious to themselves that they knew nothing about the matter. That foreign trade enriched the country, experience demonstrated to the nobles and country gentlemen, as well as to the merchants; but how, or in what manner, none of them well knew. The merchants knew perfectly in what manner it enriched themselves. It was their business to know it. But to know in what manner it enriched the country, was no part of their business. The subject never came into their consideration but when they had occasion to apply to their country for some change in the laws relating to foreign trade. It then became necessary to say something about the beneficial effects of foreign trade, and the manner in which those effects were obstructed by the laws as they then stood. To the judges who were to decide the business, it appeared a most satisfactory account of the matter, when they were told that foreign trade brought money into the country, but that the laws in question hindered it from bringing so much as it otherwise would do. Those arguments therefore produced the wished-for effect. The prohibition of exporting gold and silver was in France and England confined to the coin of those respective countries. The exportation of foreign coin and of bullion was made free. In Holland, and in some other places, this liberty was extended even to the coin of the country. The attention of government was turned away from guarding against the exportation of gold and silver, to watch over the balance of trade, as the only cause which could occasion any augmentation or diminution of those metals. From one fruitless care it was turned away to another care much more intricate, much more embarrassing, and just equally fruitless. The title of Mun's book, England's Treasure in Foreign Trade, became a fundamental maxim in the political economy, not of England only, but of all other commercial countries. The inland or home trade, the most important of all, the trade in which an equal capital affords the greatest revenue, and creates the greatest employment to the people of the country, was considered as subsidiary only to foreign trade. It neither brought money into the country, it was said, nor carried any out of it. The country, therefore, could never become either richer or poorer by means of it, except so far as its prosperity or decay might indirectly influence the state of foreign trade.

A country that has no mines of its own must undoubtedly draw its gold and silver from foreign countries, in the same manner as one that has no vineyards of its own must draw its wines. It does not seem necessary, however, that the attention of government should be more turned towards the one than towards the other object. A country that has wherewithal to buy wine, will always get the wine which it has occasion for; and a country that has wherewithal to buy gold and silver, will never be in want of those metals. They are to be bought for a certain price like all other commodities, and as they are the price of all other commodities, so all other commodities are the price of those metals. We trust with perfect security that the freedom of trade, without any attention of government, will always supply us with the wine which we have occasion for; and we may trust with equal security that it will always supply us with all the gold and silver which we can afford to purchase or to employ, either in circulating our commodities, or in other uses.

The quantity of every commodity which human industry can either purchase or produce, naturally regulates itself in every country according to the effectual demand, or according to the demand of those who are willing to pay the whole rent, labour, and profits which must be paid in order to prepare and bring it to market. But no commodities regulate themselves more easily or more exactly according to this effectual demand than gold and silver; because, on account of the small bulk and great value of those metals, no commodities can be more easily transported from one place to another, from the places where they are cheap to those where they are dear; from the places where they exceed, to those where they fall short of this effectual demand. If there was in England, for example, an effectual demand for an additional quantity of gold, a packet-boat could bring from Lisbon, or wherever else it was to be had, fifty tons of gold, which could be coined into more than five millions of guineas. But if there was an effectual demand for grain to the same value, to import it would require, at five guineas a ton, a million tons of shipping, or a thousand ships of a thousand tons each. The navy of England would not be sufficient.

When the quantity of gold and silver imported into any country exceeds the effectual demand, no vigilance of government can prevent their exportation. All the sanguinary laws of Spain and Portugal are not able to keep their gold and silver at home. The continual importations from Peru and Brazil exceed the effectual demand of those countries, and sink the price of those metals there below that in the neighbouring countries. If, on the contrary, in any particular country their quantity fell short of the effectual demand, so as to raise their price above that of the neighbouring countries, the government would have no occasion to take any pains to import them. If it was even to take pains to prevent their importation, it would not be able to effectuate it. Those metals, when the Spartans had the wherewithal to purchase them, broke through all the barriers which the laws of Lycurgus opposed to their entrance into Lacedemon. All the sanguinary laws of the customs are not able to prevent the importation of the teas of the Dutch and Gottenburg East India companies, because somewhat cheaper than those of the British company. A pound of tea, however, is about a hundred times the bulk of one of the highest prices, sixteen shillings, that is commonly paid for it in silver, and more than two thousand times the bulk of the same price in gold, and consequently just so many times more difficult to smuggle.

It is partly owing to the easy transportation of gold and silver from the places where they abound to those where they are wanted, that the price of those metals does not fluctuate continually like that of the greater part of other commodities, which are hindered by their bulk from shifting their situation, when the market happens to be either over or understocked with them. The price of those metals, indeed, is not altogether exempted from variation, but the changes to which it is liable are generally slow, gradual and uniform. In Europe, for example, it is supposed, without much foundation perhaps, that, during the course of the present and preceding century, they have been constantly, but gradually sinking in their value, on account of the continual importations from the Spanish West Indies. But to make any sudden change in the price of gold and silver, so as to raise or lower at once, sensibly and remarkably, the money price of all other commodities, requires such a revolution in commerce as that occasioned by the discovery of America.

If, notwithstanding all this, gold and silver should at any time fall short in a country which has wherewithal to purchase them, there are more expedients for supplying their place than that of almost any other commodity. If the materials of manufacture are wanted, industry must stop. If provisions are wanted, the people must starve. But if money is wanted, barter will supply its place, though with a good deal of inconveniency. Buying and selling upon credit, and the different dealers compensating their credits with one another, once a month or once a year, will supply it with less inconveniency. A well-regulated paper money will supply it, not only without inconveniency, but in some cases with some advantages. Upon every account, therefore, the attention of government never was so unnecessarily employed as when directed to watch over the preservation or increase of the quantity of money in any country.

No complaint, however, is more common than that of a scarcity of money. Money, like wine, must always be scarce with those who have neither wherewithal to buy it, nor credit to borrow it. Those who have either, will seldom be in want either of the money or of the wine which they have occasion for. This complaint, however, of the scarcity of money, is not always confined to improvident spendthrifts. It is sometimes general through a whole mercantile town, and the country in its neighbourhood. Overtrading is the common cause of it. Sober men, whose projects have been disproportioned to their capitals, are as likely to have neither wherewithal to buy money, nor credit to borrow it, as prodigals whose expense has been disproportioned to their revenue. Before their projects can be brought to bear, their stock is gone, and their credit with it. They run about everywhere to borrow money, and everybody tells them that they have none to lend. Even such general complaints of the scarcity of money do not always prove that the usual number of gold and silver pieces are not circulating in the country, but that many people want those pieces who have nothing to give for them. When the profits of trade happen to be greater than ordinary, overtrading becomes a general error both among great and small dealers. They do not always send more money abroad than usual, but they buy upon credit both at home and abroad, an unusual quantity of goods, which they send to some distant market, in hopes that the returns will come in before the demand for payment. The demand comes before the returns, and they have nothing at hand with which they can either purchase money, or give solid security for borrowing. It is not any scarcity of gold and silver, but the difficulty which such people find in borrowing, and which their creditors find in getting payment, that occasions the general complaint of the scarcity of money.

It would be too ridiculous to go about seriously to prove that wealth does not consist in money, or in gold and silver, but in what money purchases, and is valuable only for purchasing. Money, no doubt, makes always a part of the national capital; but it has already been shown that it generally makes but a small part, and always the most unprofitable part of it.

I thought it necessary, though at the hazard of being tedious, to examine at full length this popular notion, that wealth consists in money, or in gold and silver. Money in common language, as I have already observed, frequently signifies wealth; and this ambiguity of expression has rendered this popular notion so familiar to us that even they who are convinced of its absurdity are very apt to forget their own principles, and in the course of their reasonings to take it for granted as a certain and undeniable truth. Some of the best English writers upon commerce set out with observing that the wealth of a country consists, not in its gold and silver only, but in its lands, houses, and consumable goods of all kinds. In the course of their reasonings, however, the lands, houses, and consumable goods seem to slip out of their memory, and the strain of their argument frequently supposes that all wealth consists in gold and silver, and that to multiply those metals is the great object of national industry and commerce.

The two principles being established, however, that wealth consisted in gold and silver, and that those metals could be brought into a country which had no mines only by the balance of trade, or by exporting to a greater value than it imported, it necessarily became the great object of political economy to diminish as much as possible the importation of foreign goods for home consumption, and to increase as much as possible the exportation of the produce of domestic industry. Its two great engines for enriching the country, therefore, were restraints upon importation and encouragements to exportation.

The restraints upon importation were of two kinds:

First, restraints upon the importation of such foreign goods for home consumption as could be produced at home, from whatever country they were imported.

Secondly, restraints upon the importation of goods of almost all kinds from those particular countries with which the balance of trade was supposed to be disadvantageous.

Those different restraints consisted sometimes in high duties and sometimes in absolute prohibitions.

Exportation was encouraged sometimes by drawbacks, sometimes by bounties, sometimes by advantageous treaties of commerce with sovereign states, and sometimes by the establishment of colonies in distant countries.

Drawbacks were given upon two different occasions. When the home manufactures were subject to any duty or excise, either the whole or a part of it was frequently drawn back upon their exportation; and when foreign goods liable to a duty were imported in order to be exported again, either the whole or a part of this duty was sometimes given back upon such exportations.

Bounties were given for the encouragement either of some beginning manufactures, or of such sorts of industry of other kinds as were supposed to deserve particular favour.

By advantageous treaties of commerce, particular privileges were procured in some foreign state for the goods and merchants of the country, beyond what were granted to those of other countries.

By the establishment of colonies in distant countries, not only particular privileges but a monopoly was frequently procured for the goods and merchants of the country which established them.

The two sorts of restraints upon importation above mentioned, together with those four encouragements to exportation, constitute the six principal means by which the commercial system proposes to increase the quantity of gold and silver in any country by turning the balance of trade in its favour. I shall consider each of them in a particular chapter, and, without taking much further notice of their supposed tendency to bring money into the country, I shall examine chiefly what are likely to be the effects of each of them upon the annual produce of its industry. According as they tend either to increase or diminish the value of this annual produce, they must evidently tend either to increase or diminish the real wealth and revenue of the country.

OF RESTRAINTS UPON THE IMPORTATION FROM FOREIGN COUNTRIES OF SUCH GOODS AS CAN BE PRODUCED AT HOME

By restraining, either by high duties, or by absolute prohibitions, the importation of such goods from foreign countries as can be produced at home, the monopoly of the home market is more or less secured to the domestic industry employed in producing them. Thus the prohibition of importing either live cattle or salt provisions from foreign countries secures to the graziers of Great Britain the monopoly of the home market for butchers' meat. The high duties upon the importation of corn, which in times of moderate plenty amount to a prohibition, give a like advantage to the growers of that commodity. The prohibition of the importation of foreign woolens is equally favourable to the woolen manufacturers. The silk manufacture, though altogether employed upon foreign materials, has lately obtained the same advantage. The linen manufacture has not yet obtained it, but is making great strides towards it. Many other sorts of manufacturers have, in the same manner, obtained in Great Britain, either altogether, or very nearly a monopoly against their countrymen. The variety of goods of which the importation into Great Britain is prohibited, either absolutely or under certain circumstances, greatly exceeds what can easily be suspected by those who are not well acquainted with the laws of the customs.

That this monopoly of the home market frequently gives great encouragement to that particular species of industry which enjoys it, and frequently turns towards that employment a greater share of both the labour and stock of the society than would otherwise have gone to it, cannot be doubted. But whether it tends either to increase the general industry of the society, or to give it the most advantageous direction, is not, perhaps, altogether so evident.

The general industry of the society can never exceed what the capital of the society can employ. As the number of workmen that can be kept in employment by any particular person must bear a certain proportion to his capital, so the number of those that can be continually employed by all the members of a great society, must bear a certain proportion to the whole capital of that society, and never can exceed that proportion. No regulation of commerce can increase the quantity of industry in any society beyond what its capital can maintain. It can only divert a part of it into a direction into which it might not otherwise have gone; and it is by no means certain that this artificial direction is likely to be more advantageous to the society than that into which it would have gone of its own accord.

Every individual is continually exerting himself to find out the most advantageous employment for whatever capital he can demand. It is his own advantage, indeed, and not that of the society, which he has in view. But the study of his own advantage naturally, or rather necessarily, leads him to prefer that employment which is most advantageous to the society.

First, every individual endeavours to employ his capital as near home as he can, and consequently as much as he can in the support of domestic industry; provided always that he can thereby obtain the ordinary, or not a great deal less than the ordinary, profits of stock.

Thus upon equal or nearly equal profits, every wholesale merchant naturally prefers the home trade to the foreign trade of consumption, and the foreign trade of consumption to the carrying trade. In the home trade his capital is never so long out of his sight as it frequently is in the foreign trade of consumption. He can know better the character and situation of the persons whom he trusts, and, if he should happen to be deceived, he knows better the laws of the country from which he must seek redress. In the carrying trade, the capital of the merchant is, as it were, divided between two foreign countries, and no part of it is ever necessarily brought home, or placed under his own immediate view and command. The capital which an Amsterdam merchant employs in carrying corn from Konigsberg to Lisbon, and fruit and wine from Lisbon to Konigsberg, must generally be the one-half of it at Konigsberg and the other half at Lisbon. No part of it need ever come to Amsterdam. The natural residence of such a merchant should either be at Konigsberg or Lisbon, and it can only be some very particular circumstance which can make him prefer the residence of Amsterdam. The uneasiness, however, which he feels at being separated so far from his capital, generally determines him to bring that part both of the Konigsberg goods which he destines for the market of Lisbon, and of the Lisbon goods which he destines for that of Konigsberg, to Amsterdam, and though this necessarily subjects him to a double charge of loading and unloading, as well as to the payment of some duties and customs, yet for the sake of having some part of his capital always under his own view and command, he willingly submits to this extraordinary charge; and it is in this manner that every country which has any considerable share of the carrying trade, becomes always the emporium, or general market, for the goods of all the different countries whose trade it carries on. The merchant, in order to save a second loading and unloading, endeavours always to sell in the home market as much of the goods of all those different countries as he can, and thus, so far as he can, to convert his carrying trade into a foreign trade of consumption. A merchant, in the same manner, who is engaged in the foreign trade of consumption, when he collects goods for foreign markets, will always be glad, upon equal or nearly equal profits, to sell as great a part of them at home as he can. He saves himself the risk and trouble of exportation, when, so far as he can, he thus converts his foreign trade of consumption into a home trade. Home is in this manner the centre, if I may say so, round which the capitals of the inhabitants of every country are continually circulating, and towards which they are always tending, though by particular causes they may sometimes be driven off and repelled from it towards more distant employments. But a capital employed in a home trade, it has already been shown, necessarily puts into motion a greater quantity of domestic industry and gives revenue and employment to a greater number of the inhabitants of the country, than an equal capital employed in the foreign trade of consumption; and one employed in the foreign trade of consumption has the same advantage over an equal capital employed in the carrying trade. Upon equal, or only nearly equal profits, therefore, every individual naturally inclines to employ his capital in the manner in which it is likely to afford the greatest support to domestic industry, and to give revenue and employment to the greatest number of people of his own country.

Secondly, every individual who employs his capital in the support of domestic industry, necessarily endeavours to so direct that industry, that its produce may be of the greatest possible value.

The produce of industry is what it adds to the subject or materials upon which it is employed. In proportion as the value of this produce is great or small, so will likewise be the profits of the employer. But it is only for the sake of profit that any man employs a capital in the support of industry; and he will always, therefore, endeavour to employ it in the support of that industry of which the produce is likely to be of the greatest value, or to exchange for the greatest quantity either of money or of other goods.

But the annual revenue of every society is always precisely equal to the exchangeable value of the whole annual produce of its industry, or rather is precisely the same thing with that exchangeable value. As every individual, therefore, endeavours as much as he can both to employ his capital in the support of domestic industry, and so to direct that industry that its produce may be of the greatest value, every individual necessarily labours to render the annual revenue of the society as great as he can. He generally, indeed, neither intends to promote the public interest, nor knows how much he is promoting it. By preferring the support of domestic to that of foreign industry, he intends only his own security; and by directing that industry in such a manner as its produce may be of the greatest value, he intends only his own gain, and he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention. Nor is it always the worse for the society that it was no part of it. By pursuing his own interest he frequently promotes that of the society more effectually than when he really intends to promote it. I have never known much good done by those who affected to trade for the public good. It is an affectation, indeed, not very common among merchants, and very few words need be employed in dissuading them from it.

What is the species of domestic industry which his capital can employ, and of which the produce is likely to be of the greatest value, every individual, it is evident, can, in his local situation, judge much better than any statesman or lawgiver can do for him. The statesman who should attempt to direct private people in what manner they ought to employ their capitals would not only load himself with a most unnecessary attention, but assume an authority which could safely be trusted, not only to no single person, but to no council or senate whatever, and which would nowhere be so dangerous as in the hands of a man who had folly and presumption enough to fancy himself fit to exercise it.

To give the monopoly of the home market to the produce of domestic industry, in any particular art or manufacture, is in some measure to direct private people in what manner they ought to employ their capitals, and must, in almost all cases, be either a useless or a hurtful regulation. If the produce of domestic can be brought there as cheap as that of foreign industry, the regulation is evidently useless. If it cannot, it must generally be hurtful. It is the maxim of every prudent master of a family never to attempt to make at home what it will cost him more to make than to buy. The tailor does not attempt to make his own shoes, but buys them of the shoemaker. The shoemaker does not attempt to make his own clothes, but employs a tailor. The farmer attempts to make neither the one nor the other, but employs those different artificers. All of them find it for their interest to employ their whole industry in a way in which they have some advantage over their neighbours, and to purchase with a part of its produce, or, what is the same thing, with the price of a part of it, whatever else they have occasion for.

What is prudence in the conduct of every private family, can scarce be folly in that of a great kingdom. If a foreign country can supply us with a commodity cheaper than we ourselves can make it, better buy it of them with some part of the produce of our own industry, employed in a way in which we have some advantage. The general industry of the country, being always in proportion to the capital which employs it, will not thereby be diminished, no more than that of the above mentioned artificers, but only left to find out the way in which it can be employed with the greatest advantage. It is certainly not employed to the greatest advantage when it is thus directed towards an object which it can buy cheaper than it can make. The value of its annual produce is certainly more or less diminished when it is thus turned away from producing commodities evidently of more value than the commodity which it is directed to produce. According to the supposition, that commodity could be purchased from foreign countries cheaper than it can be made at home. It could, therefore, have been purchased with a part only of the commodities, or, what is the same thing, with a part only of the price of the commodities, which the industry employed by an equal capital would have produced at home, had it been left to follow its natural course. The industry of the country, therefore, is thus turned away from a more to a less advantageous employment, and the exchangeable value of its annual produce, instead of being increased, according to the intention of the lawgiver, must necessarily be diminished by every such regulation.

By means of such regulations, indeed, a particular manufacture may sometimes be acquired sooner than it could have been otherwise, and after a certain time may be made at home as cheap or cheaper than in the foreign country. But though the industry of the society may be thus carried with advantage into a particular channel sooner than it could have been otherwise, it will by no means follow that the sum total, either of its industry or of its revenue, can ever be augmented by any such regulation. The industry of the society can augment only in proportion as its capital augments, and its capital can augment only in proportion to what can be gradually saved out of its revenue. But the immediate effect of every such regulation is to diminish its revenue, and what diminishes its revenue is certainly not very likely to augment its capital faster than it would have augmented of its own accord, had both capital and industry been left to find out their natural employments.

Though for want of such regulations the society should never acquire the proposed manufacture, it would not, upon that account, necessarily be the poorer in any one period of its duration. In every period of its duration its whole capital and industry might still have been employed, though upon different objects, in the manner that was most advantageous at the time. In every period its revenue might have been the greatest which its capital could afford, and both capital and revenue might have been augmented with the greatest possible rapidity.

The natural advantages which one country has over another in producing particular commodities are sometimes so great that it is acknowledged by all the world to be in vain to struggle with them. By means of glasses, hot-beds, and hot-walls, very good grapes can be grown in Scotland, and very good wine, too, can be made of them, at about thirty times the expense for which at least equally good can be brought from foreign countries. Would it be a reasonable law to prohibit the importation of all foreign wines, merely to encourage the making of claret and burgundy in Scotland? But if there would be a manifest absurdity in turning towards any employeemnt thirty times more of the capital and industry of the country than would be necessary to purchase from foreign countries an equal quantity of the commodities wanted, there must be an absurdity, though not altogether so glaring, yet exactly of the same kind, in turning towards any such employment a thirtieth or even a three-hundredth part more of either. Whether the advantages which one country has over another be natural or acquired, is in this respect of no consequence. As long as the one country has those advantages and the other wants them, it will always be more advantageous for the latter rather to buy of the former than to make. It is an acquired advantage only which one artificer has over his neighbour who exercises another trade; and yet they both find it more advantageous to buy of one another than to make what does not belong to their particular trades.

Merchants and manufacturers are the people who derive the greatest advantage from this monopoly of the home market. The prohibition of the importation of foreign cattle and of salt provisions, together with the high duties upon foreign corn, which in times of moderate plenty amount to a prohibition, are not near so advantageous to the graziers and farmers of Great Britain as other regulations of the same kind are to its merchants and manufacturers. Manufactures, those of the finer kind especially, are more easily transported from one country to another than corn or cattle. It is in the fetching and carrying manufactures, accordingly, that foreign trade is chiefly employed. In manufactures a very small advantage will enable foreigners to undersell our own workmen, even in the home market. It will require a very great one to enable them to do so in the rude produce of the soil. If the free importation of foreign manufactures was permitted, several of the home manufactures would probably suffer, and some of them perhaps go to ruin altogether, and a considerable part of the stock and industry at present employed in them would be forced to find out some other employment. But the freest importation of the rude produce of the soil could have no such effect upon the agriculture of the country.

If the importation of foreign cattle, for instance, was made ever so free, so few could be imported that the grazing trade of Great Britain could be little affected by it. Live cattle are, perhaps, the only commodity of which the transportation is more expensive by sea than by land. By land, they carry themselves to market. By sea, not only the cattle, but their food and their water, too, must be carried at no small expense and inconveniency. The short sea between Ireland and Great Britain, indeed, renders the importation of Irish cattle more easy. But though the free importation of them, which was lately permitted only for a limited time, were rendered perpetual, it could have no considerable effect upon the interest of the graziers of Great Britain. Those parts of Great Britain which border upon the Irish Sea are all grazing countries. Irish cattle could never be imported for their use, but must be drove through those very extensive countries, at no small expense and inconveniency, before they could arrive at their proper market. Fat cattle could not be drove so far. Lean cattle therefore only could be imported, and such importation could interfere, not with the interest of the feeding or fattening countries, to which, by reducing the price of lean cattle, it would rather be advantageous, but with that of the breeding countries only. The small number of Irish cattle imported since their importation was permitted, together with the good price at which lean cattle continue to sell, seem to demonstrate that even the breeding countries of Great Britain are never likely to be much affected by the free importation of Irish cattle. The common people of Ireland, indeed, are said to have sometimes opposed with violence the exportation of their cattle. But if the exporters had found any great advantage in continuing the trade, they could easily, when the law was on their side, have conquered this mobbish opposition.

Feeding and fattening countries, besides, must always be highly improved, whereas breeding countries are generally uncultivated. The high price of lean cattle, by augmenting the value of uncultivated land, is like a bounty against improvement. To any country which was highly improved throughout, it would be more advantageous to import its lean cattle than to breed them. The province of Holland, accordingly, is said to follow this maxim at present. The mountains of Scotland, Wales, and Northumberland, indeed, are countries not capable of much improvement, and seem destined by nature to be the breeding countries of Great Britain. The freest importation of foreign cattle could have no other effect than to hinder those breeding countries from taking advantage of the increasing population and improvement of the rest of the kingdom, from raising their price to an exorbitant height, and from laying a real tax upon all the more improved and cultivated parts of the country.

The freest importation of salt provisions, in the same manner, could have as little effect upon the interest of the graziers of Great Britain as that of live cattle. Salt provisions are not only a very bulky commodity, but when compared with fresh meat they are a commodity both of worse quality, and as they cost more labour and expense, of higher price. They could never, therefore, come into competition with the fresh meat, though they might with the salt provisions of the country. They might be used for victualling ships for distant voyages, and such like uses, but could never make any considerable part of the food of the people. The small quantity of salt provisions imported from Ireland, since their importation was rendered free, is an experimental proof that our graziers having nothing to apprehend from it. It does not appear that the price of butchers' meat has ever been sensibly affected by it.

Even the free importation of foreign corn could very little affect the interest of the farmers of Great Britain. Corn is a much more bulky commodity than butchers' meat. A pound of wheat at a penny is as dear as a pound of butchers' meat at fourpence. The small quantity of foreign corn imported even in times of the greatest scarcity, may satisfy our farmers that they can have nothing to fear from the freest importation. The average quantity imported, one year with another, amounts only, according to the well-informed author of the tracts upon the corn trade, to twenty-three thousand seven hundred and twenty-eight quarters of all sorts of grain, and does not exceed the five hundred and seventy-first part of the annual consumption. But as the bounty upon corn occasions a greater exportation in years of plenty, so it must of consequence occasion a greater importation in years of scarcity, than in the actual state of tillage would otherwise take place. By means of it, the plenty of one year does not compensate the scarcity of another, and as the average quantity exported is necessarily augmented by it, so must likewise, in the actual state of tillage, the average quantity imported. If there was no bounty, as less corn would be exported, so it is probable that, one year with another, less would be imported than at present. The corn merchants, the fetchers and carriers of corn between Great Britain and foreign countries, would have much less employment, and might suffer considerably; but the country gentleman and farmers could suffer very little. It is in the corn merchants, accordingly, rather than in the country gentleman and farmers, that I have observed the greatest anxiety for the renewal and continuation of the bounty.

Country gentlemen and farmers are, to their great honour, of all people the least subject to the wretched spirit of monopoly. The undertaker of a great manufactory is sometimes alarmed if another work of the same kind is established within twenty miles of him. The Dutch undertaker of the woolen manufacture at Abbeville stipulated that no work of the same kind should be established within thirty leagues of that city. Farmers and country gentlemen, on the contrary, are generally disposed rather to promote than to obstruct the cultivation of their neighbour's farms and estates. They have no secrets, such as those of the greater part of manufacturers, but are generally rather fond of communicating to their neighbours, and of extending as far as possible, any new practice which they have found to be advantageous. *Pius Questus,* says old Cato, *stabilissimusque, minimeque invidiosus; minimeque male cogitantes sunt, qui in eo studio occupati sunt.* Country gentlemen and farmers, dispersed in different parts of the country, cannot so easily combine as merchants and manufacturers, who, being collected into towns and accustomed to that exclusive corporation spirit which prevails in them, naturally endeavour to obtain against all their countrymen the same exclusive privilege which they generally possess against the inhabitants of their respective towns. They accordingly seem to have been the original inventors of those restraints upon the importation of foreign goods which secure to them the monopoly of the home market. It was probably in imitation of them, and to put themselves upon a level with those who they found were disposed to oppress them, that the country gentlemen and farmers of Great Britain so far forgot the generosity which is natural to their station as to demand the exclusive privilege of supplying their countrymen with corn and butchers' meat. They did not perhaps take time to consider how much less their interest could be affected by the freedom of trade than that of the people whose example they followed.

To prohibit by a perpetual law the importation of foreign corn and cattle is, in reality, to enact that the population and industry of the country shall at no time exceed what the rude produce of its own soil can maintain.

There seem, however, to be two cases in which it will generally be advantageous to lay some burden upon foreign for the encouragement of domestic industry.

The first is, when some particular sort of industry is necessary for the defense of the country. The defense of Great Britain, for example, depends very much upon the number of its sailors and shipping. The Act of Navigation, therefore, very properly endeavours to give the sailors and the shipping of Great Britain the monopoly of the trade of their own country, in some cases by absolute prohibitions, and in others by heavy burdens upon the shipping of foreign countries. The following are the principal dispositions of this act:

First, all ships, of which the owners, masters, and three-fourths of the mariners are not British subjects, are prohibited, upon pain of forfeiting ship and cargo, from trading to the British settlements and plantations, or from being employed in the coasting trade of Great Britain.

Secondly, a great variety of the most bulky articles of importation can be brought into Great Britain only, either in such ships as are above described, or in ships of the country where those goods are produced, and of which the owners, masters, and three-fourths of the mariners are of that particular country; and when imported even in ships of this latter kind, they are subject to double aliens-duty. If imported in ships of any other country, the penalty is forfeiture of ship and goods. When this Act was made, the Dutch were, what they still are, the great carriers of Europe, and by this regulation they were entirely excluded from being the carriers to Great Britain, or from importing to us the goods of any other European country.

Thirdly, a great variety of the most bulky articles of importation are prohibited from being imported, even in British ships, from any country but that in which they are produced, upon pain of forfeiting ship and cargo. This regulation, too, was probably intended against the Dutch. Holland was then, as now, the great emporium for all European goods, and by this regulation British ships were hindered from loading in Holland the goods of any other European country.

Fourthly, salt fish of all kinds, whale-fins, whalebone, oil, and blubber, not caught by and cured on board British vessels, when imported into Great Britain, are subjected to double aliens-duty. The Dutch, as they are still the principal, were then the only fishers in Europe that attempted to supply foreign nations with fish. By this regulation a very heavy burden was laid upon their supplying Great Britain.

When the Act of Navigation was made, though England and Holland were not actually at war, the most violent animosity subsisted between the two nations. It had begun during the government of the

Long Parliament, which first framed this Act, and it broke out soon after in the Dutch wars during that of the Protector and of Charles the Second. It is not impossible, therefore, that some of the regulations of this famous Act may have proceeded from national animosity. They are as wise, however, as if they had all been dictated by the most deliberate wisdom. National animosity at that particular time aimed at the very same object which the most deliberate wisdom would have recommended, the diminution of the naval power of Holland, the only naval power which could endanger the security of England.

The Act of Navigation is not favourable to foreign commerce, or to the growth of that opulence which can arise from it. The interest of a nation in its commercial relations to foreign nations is, like that of a merchant with regard to the different people with whom he deals, to buy as cheap and to sell as dear as possible. But it will be most likely to buy cheap, when by the most perfect freedom of trade it encourages all nations to bring to it the goods which it has occasion to purchase; and for the same reason, it will be most likely to sell dear, when its markets are thus filled with the greatest number of buyers. The Act of Navigation, it is true, lays no burden upon foreign ships that come to export the produce of British industry. Even the ancient aliens-duty, which used to be paid upon all goods exported as well as imported, has, by several subsequent acts, been taken off from the greater part of the articles of exportation. But if foreigners, either by prohibitions or high duties, are hindered from coming to sell, they cannot always afford to come to buy; because, coming without a cargo, they must lose the freight from their own country to Great Britain. By diminishing the number of sellers, therefore, we necessarily diminish that of buyers, and are thus likely not only to buy foreign goods dearer, but to sell our own cheaper, than if there was a more perfect freedom of trade. As defense, however, is of much more importance than opulence, the Act of Navigation is, perhaps, the wisest of all commercial regulations of England.

The second case, in which it will generally be advantageous to lay some burden upon foreign for the encouragement of domestic industry, is when some tax is imposed at home upon the produce of the latter. In this case it seems reasonable that an equal tax should be imposed upon the like produce of the former. This would not give the monopoly of the home market to domestic industry, nor turn towards a particular employment a greater share of the stock and labour of the country than what would naturally go to it. It would only hinder any part of what would naturally go to it from being turned away by the tax into a less natural direction, and would leave the competition between foreign and domestic industry, after the tax, as nearly as possible upon the same footing as before it. In Great Britain, when any such tax is laid upon the produce of domestic industry, it is usual at the same time, in order to stop the clamorous complaints of our merchants and manufacturers, that they will be undersold at home, to lay a much heavier duty upon the importation of all foreign goods of the same kind.

This second limitation of the freedom of trade, according to some people should, upon some occasions, be extended much further than to the precise foreign commodities which could come into competition with those which had been taxed at home. When the necessaries of life have been taxed in any country, it becomes proper, they pretend, to tax not only the like necessaries of life imported from other countries, but all sorts of foreign goods which can come into competition with anything that is the produce of domestic industry. Subsistence, they say, becomes necessarily dearer in consequence of such taxes; and the price of labour must always rise with the price of the labourer's subsistence. Every commodity, therefore, which is the produce of domestic industry, though not immediately taxed itself, becomes dearer in consequence of such taxes, because the labour which produces it becomes so. Such taxes, therefore, are really equivalent, they say, to a tax upon every particular commodity produced at home. In order to put domestic upon the same footing with foreign industry, therefore, it becomes necessary, they think, to lay some duty upon every foreign commodity, equal to this enhancement of the price of the home commodities with which it can come into competition.

Whether taxes upon the necessaries of life, such as those in Great Britain upon soap, salt, leather, candles, etc., necessarily raise the price of labour, and consequently that of all other commodities, I shall consider hereafter, when I come to treat of taxes. Supposing, however, in the meantime, that they have this effect, and they have it undoubtedly, this general enhancement of the price of all commodities, in consequence of that of labour, is a case which differs in the two following respects from that of a particular commodity, of which the price was enhanced by a particular tax immediately imposed upon it.

First, it might always be known with great exactness how far the price of such a commodity could be enhanced by such a tax; but how far the general enhancement of the price of labour might affect that of every different commodity, about which labour was employed, could never be known with any tolerable exactness. It would be impossible, therefore, to proportion with any tolerable exactness the tax upon every foreign, to this enhancement of the price of every home commodity.

Secondly, taxes upon the necessaries of life have nearly the same effect upon the circumstances of the people as a poor soil and a bad climate. Provisions are thereby rendered dearer in the same manner as if it required extraordinary labour and expense to raise them. As in the natural scarcity arising from soil and climate, it would be absurd to direct the people in what manner they ought to employ their capitals and industry, so it is likewise in the artificial scarcity arising from such taxes. To be left to accommodate, as well as they could, their industry to their situation, and to find out those employments in which, notwithstanding their unfavourable circumstances, they might have some advantage either in the home or in the foreign market, is what in both cases would evidently be most for their advantage. To lay a new tax upon them, because they are already overburdened with taxes, and because they already pay too dear for the necessaries of life, to make them likewise pay too dear for the greater part of other commodities, is certainly a most absurd way of making amends.

Such taxes, when they have grown up to a certain height, are a curse equal to the barrenness of the earth and the inclemency of the heavens; and yet it is in the richest and most industrious countries that they have been most generally imposed. No other countries could support so great a disorder. As the strongest bodies only can live and enjoy health under an unwholesome regimen, so the nations only, that in every sort of industry have the greatest natural and acquired advantages, can subsist and prosper under such taxes. Holland is the country in Europe in which they abound most, and which from peculiar circumstances continues to prosper, not by means of them, as has been most absurdly supposed, but in spite of them.

As there are two cases in which it will generally be advantageous to lay some burden upon foreign, for the encouragement of domestic industry, so there are two others in which it may sometimes be a matter of deliberation: in the one, how far it is proper to continue the free importation of certain foreign goods; and in the other, how far or in what manner it may be proper to restore that free importation after it has been for some time interrupted.

The case in which it may sometimes be a matter of deliberation how far it is proper to continue the free importation of certain foreign goods, is when some foreign nation restrains by high duties or prohibitions the importation of some of our manufactures into their country. Revenge in this case naturally dictates retaliation, and that we should impose the like duties and prohibitions upon the importation of some or all of their manufactures into ours. Nations, accordingly, seldom fail to retaliate in this manner. The French have been particularly forward to favour their own manufactures by restraining the importation of such foreign goods as could come into competition with them. In this consisted a great part of the policy of M. Colbert, who, notwithstanding his great abilities, seems in this case to have been imposed upon by the sophistry of merchants and manufacturers, who are always demanding a monopoly against their countrymen. It is at present the opinion of the most intelligent men in France that his operations of this kind have not been beneficial to his country. That minister, by the tariff of 1667, imposed very high duties upon a great number of foreign manufactures. Upon his refusing to moderate them in favour of the Dutch, they in 1671 prohibited the importation of the wines, brandies, and manufactures of France. The war of 1672 seems to have been in part occasioned by this commercial dispute. The peace of Nimeguen put an end to it in 1678, by moderating some of those duties in favour of the Dutch, who in consequence took off their prohibition. It was about the same time that the French and English began mutually to oppress each other's industry, by the like duties and prohibitions, of which the French, however, seem to have set the first example. The spirit of hostility which has subsisted between the two nations ever since, has hitherto hindered them from being moderated on either side. In 1697 the English prohibited the importation of bone-lace, the manufacture of Flanders. The government of that country, at that time under the dominion of Spain, prohibited in return the importation of English woolens. In 1700, the prohibition of importing bone-lace into England was taken off, upon condition that the importation of English woolens into Flanders should be put on the same footing as before.

There may be good policy in retaliations of this kind, when there is a probability that they will procure the repeal of the high duties or prohibitions complained of. The recovery of a great foreign market will generally more than compensate the transitory inconveniency of paying dearer during a short time for some sorts of goods. To judge whether such retaliations are likely to produce such an effect, does not perhaps, belong so much to the science of a legislator, whose deliberations ought to be governed by general principles which are always the same, as to the skill of that insidious and crafty animal, vulgarly called a statesman or politician, whose councils are directed by the momentary fluctuations of affairs. When there is no probability that any such repeal can be procured, it seems a bad method of compensating the injury done to certain classes of our people, to do another injury ourselves, not only to those classes, but to almost all the other classes of them. When our neighbours prohibit some manufacture of ours, we generally prohibit, not only the same, for that alone would seldom affect them considerably, but some other manufacture of theirs. This may no doubt give encouragement to some particular class of workmen among ourselves, and by excluding some of their rivals, may enable them to raise their price in the home market. Those workmen, however, who suffered by our neighbours' prohibition will not be benefited by ours. On the contrary, they and almost all the other classes of our citizens will thereby be obliged to pay dearer than before for certain goods. Every such law, therefore, imposes a real tax upon the whole country, not in favour of that particular class of workmen who were injured by our neighbours' prohibition, but of some other class.

The case in which it may sometimes be a matter of deliberation, how far or in what manner it is proper to restore the free importation of foreign goods, after it has been for some time interrupted, is, when particular manufactures, by means of high duties or prohibitions upon all foreign goods which can come into competition with them, have been so far extended as to employ a great multitude of hands. Humanity may in this case require that the freedom of trade should be restored only by slow gradations, and with a good deal of reserve and circumspection. Were those high duties and prohibitions taken away all at once, cheaper foreign goods of the same kind might be poured so fast into the home market, as to deprive all at once many thousands of our people of their ordinary employment and means of subsistence. The disorder which this would occasion might no doubt be very considerable. It would in all probability, however, be much less than is commonly imagined, for the two following reasons:

First, all those manufactures, of which any part is commonly exported to other European countries without a bounty, could be very little affected by the freest importation of foreign goods. Such manufactures must be sold as cheap abroad as any other foreign goods of the same quality and kind, and consequently must be sold cheaper at home. They would still, therefore, keep possession of the home market, and though a capricious man of fashion might sometimes prefer foreign wares, merely because they were foreign, to cheaper and better goods of the same kind that were made at home, this folly could, from the nature of things, extend to so few that it could make no sensible impression upon the general employment of the people. But a great part of all the different branches of our woolen manufacture, of our tanned leather, and of our hardware, are annually exported to other European countries without any bounty, and these are the manufactures which employ the greatest number of hands. The silk, perhaps, is the manufacture which would suffer the most by this freedom of trade, and after it the linen, although the latter much less than the former.

Secondly, though a great number of people should, by thus restoring the freedom of trade, be thrown all at once out of their ordinary employment and common method of subsistence, it would by no means follow that they would thereby be deprived either of employment or subsistence. By the reduction of the army and navy at the end of the late war, more than a hundred thousand soldiers and seamen, a number equal to what is employed in the greatest manufactures, were all at once thrown out of their ordinary employment; but though they no doubt suffered some inconveniency, they were not thereby deprived of all employment and subsistence. The greater part of the seamen, it is probable, gradually betook themselves to the merchant service as they could find occasion, and in the meantime both they and the soldiers were absorbed in the great mass of the people and employed in a great variety of occupations. Not only no great convulsion, but no sensible disorder arose from so great a change in the situation of more than a hundred thousand men, all accustomed to the use of arms, and many of them to rapine and plunder. The number of vagrants was scarce anywhere sensibly increased by it, even the wages of labour were not reduced by it in any occupation, so far as I have been able to learn, except in that of seamen in the merchant service. But if we compare together the habits of a soldier and of any sort of manufacturer, we shall find that those of the latter do not tend so much to disqualify him from being employed in a new trade, as those of the former from being employed in any. The manufacturer has always been accustomed to look for his subsistence from his labour only; the soldier to expect it from his pay. Application and industry have been familiar to the one; idleness and dissipation to the other. But it is surely much easier to change the direction of industry from one sort of labour to another, than to turn idleness and dissipation to any. To the greater part of manufactures besides, it has already been observed, there are other collateral manufactures of so similar a nature, that a workman can easily transfer his industry from one of them to another. The greater part of such workmen, too, are occasionally employed in country labour. The stock which employed them in a particular manufacture before, will still remain in the country to employ an equal number of people in some other way. The capital of the country remaining the same, the demand for labour will likewise be the same, or very nearly the same, though it may be exerted in different places and for different occupations. Soldiers and seamen, indeed, when discharged from the king's service, are at liberty to exercise any trade, within any town or place in Great Britain and Ireland. Let the same natural liberty of exercising what species of industry they please be restored to all his Majesty's subjects in the same manner as to soldiers and seamen; that is, break down the exclusive privilege of corporations and repeal the statute of apprenticeship, both which are real encroachments upon natural liberty, and add to these the repeal of the law of settlements, so that a poor workman, when thrown out of employment, either in one trade or in one place, may seek for it in another trade or in another place, without the fear either of a prosecution or of a removal, and neither the public nor the individuals will suffer much more from the occasional disbanding of some particular class of manufactures, than from that of soldiers. Our manufacturers have no doubt great merit with their country, but they cannot have more than those who defend it with their blood, nor deserve to be treated with more delicacy.

To expect, indeed, that the freedom of trade should ever be entirely restored in Great Britain, is as absurd as to expect that an Oceana or Utopia should ever be established in it. Not only the prejudices of the public, but what is much more unconquerable, the private interests of many individuals, irresistibly oppose it. Were the officers of the army to oppose with the same zeal and unanimity any reduction in the number of forces, with which master manufacturers set themselves against every law that is likely to increase the number of their rivals in the home market; were the former to animate their soldiers, in the same manner as the latter inflame their workmen, to attack with violence and outrage the proposers of any such regulation; to attempt to reduce the army would be as dangerous as it has now become to attempt to diminish in any respect the monopoly which our manufacturers have obtained against us. This monopoly has so much increased the number of some particular tribes of them that, like an overgrown standing army, they have become formidable to the government, and upon many occasions intimidate the legislature. The member of parliament who supports every proposal for strengthening this monopoly is sure to acquire not only the reputation of understanding trade, but great popularity and influence with an order of men whose numbers and wealth render them of great importance. If he opposes them, on the contrary, and still more, if he has authority enough to be able to thwart them, neither the most acknowledged probity, nor the highest rank, nor the greatest public services can protect him from the most infamous abuse and detraction, from personal insults, nor sometimes from real danger, arising from the insolent outrage of furious and disappointed monopolists.

The undertaker of a great manufacture who, by the home markets being suddenly laid open to the competition of foreigners, should be obliged to abandon his trade, would no doubt suffer very considerably. That part of his capital which had usually been employed in purchasing materials and in paying his workmen might, without much difficulty, perhaps, find another employment. But that part of it which was fixed in workhouses, and in the instruments of trade, could scarce be disposed of without considerable loss. The equitable regard, therefore, to his interest requires that changes of this kind should never be introduced suddenly, but slowly, gradually, and after a very long warning. The legislature, were it possible that its deliberations could be always directed, not by the clamorous importunity of partial interests, but by an extensive view of the general good, ought upon this very account, perhaps, to be particularly careful neither to establish any new monopolies of this kind, nor to extend further those which are already established. Every such regulation introduces some degree of real disorder into the constitution of the State, which it will be difficult hereafter to cure without occasioning another disorder.

How far it may be proper to impose taxes upon the importation of foreign goods, in order, not to prevent their importation, but to raise a revenue for Government, I shall consider hereafter when I come to treat of taxes. Taxes imposed with a view to prevent, or even to diminish importation, are evidently as destructive of the revenue of the customs as of the freedom of trade.

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